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THE SOLAR ATMOSPHERE.

By Captain JOHN ERICSSON.

From "Nature."

The object of the investigation discussed in "Nature" (No. 101, pp. 449–452) being merely that of ascertaining whether the incandescent matter contained in the solar atmosphere transmits radiant heat of sufficient energy to admit of thermometric measurement, no particular statement was deemed necessary regarding the spectrum which appeared on the bulb of the focal thermometer after shutting out the rays from the photosphere during the experiments. The appearance of this spectrum has in the meantime been carefully considered. Its extent and position suggests that the depth of the solar atmosphere far exceeds the limits hitherto assumed.

The accompanying frontispiece represents an apparatus constructed by the writer to facilitate the investigation.

Evidently the expedient of shutting out the photosphere while examining the effect produced by the rays emanating from the chromosphere, calls for means by which the sun may be kept accurately in focus during the period required to complete the observations. The main features of the apparatus being shown by the illustration, a brief description will suffice. The parabolic reflector which concentrates the rays from the chromosphere (described in the previous article) is placed in the cavity of a conical dish of cast iron, secured to the top of a table suspended on 2 horizontal journals, and revolving on a vertical axle. The latter, slightly taper, turns in a cast-iron socket, which is bushed with brass and supported by 3 legs stepped on a triangular base, resting on friction rollers. The horizontal journals referred to turn in bearings attached to a rigid bar of wrought iron situated under the table, firmly secured to the upper end of the vertical axle. The horizontal angular position of the table is adjusted by a screw operated by the small hand-wheel *a*, the inclination being regulated by another screw turned by the hand-wheel *b*. A graduated quadrant, *e*, is attached to the end of the table in order to afford means of ascertaining the sun's zenith distance at any moment. The index *d*, which marks the degree of inclination, is stationary, being secured to the rigid bar before described. The rays from the photosphere are shut out by a circular disc *f*, composed of sheet metal turned to exact size, and supported by 3 diagonal rods of steel. These rods are secured to the circumference of the conical dish by screws and adjustable nuts in such a manner that the centre of the disc *f* may readily be brought in a direct line with the axis of the reflector. The mechanism adopted for adjusting the position of the table by the hand-wheels *a* and *b*, requires no explanation; but the device which enables the operator to ascer-

tain when the axis of the reflector is pointed exactly towards the centre of the sun demands particular notice. A shallow cylindrical box *g*, provided with a flat lid and open at the bottom, excepting a narrow flange extending round the circumference, is firmly held by 2 columns secured to the top of the table. A convex lens of 26 in. focus is inserted in the cylindrical box, the narrow flange mentioned affording necessary support. The lid is perforated by 2 openings at right angles, 0.05 in. wide, 2.5 in. long, forming a cross, the lens being so adjusted that its axis passes through the central point of intersection of the cross. The face of the table being turned at right angles to the sun, or nearly so, it will be evident that the rays passing through the perforations and through the lens will produce, at a certain distance, a brilliantly illuminated cross of small size and sharp outline. A piece of ivory or white paper, on which parallel lines are drawn intersecting each other at right angles, is attached to the top of the table in such a position that the centre of intersection of the said lines coincides with the axis of the lens. This axis being parallel with the line passing through the centre of the disc *f* and the focus of the reflector, it will be perceived that the operator, in directing the table, has only to bring the illuminated cross within the intersecting parallel lines on the piece of ivory. Ample practice has shown that by this arrangement an attentive person can easily keep the disc *f* accurately in line with the focus of the reflector and the centre of the sun during any desirable length of time. The absence of any perceptible motion of the column of the focal thermometer during the experiments which have been made, furnishes the best evidence that the sun's rays have been effectually shut out by the intervening disc, which, it should be remembered, is only large enough to screen the aperture of the reflector from the rays projected by the photosphere. It may be noticed that actinometric observations cannot be accurately made unless the instrument is attached to a table capable of being directed in the manner described; nor is it possible to measure the dynamic energy transmitted by solar radiation unless the calorimeter employed for the purpose faces the sun with the same precision as our parabolic reflector.

It is worthy of notice that the lightness of the illustrated apparatus renders exact adjustment easy, since screws of small diameter and fine pitch may be employed. It only remains to be stated that in order to admit of accurate examination of the spectrum before referred to, the thermometer is removed during investigations which do not relate to temperature, a cylindrical stem of metal, 0.25 in. diameter, coated with lamp black, being introduced in its place.

With reference to the result of recent experiments, it is proper to state that, at the present time, the sun's zenith distance being now nearly 60 deg. at noon, no perceptible heating takes place in the focus of the parabolic reflector. The observations relating to temperature, mentioned in the previous article, were made when the zenith distance was only $\frac{1}{2}$ of what it is at present. The consequent increase of atmospheric depth, at this time, has completely changed the color of the spectrum, and rendered the same so feeble that its extent cannot be determined. As seen last summer, before the earth had receded far from the aphelion, the termination of the spectrum reached so far down that an addition of 0.15 in. to the radius of the disc *f* would scarcely have shut it out. Now an addition of 0.15 in. to the radius of the disc corresponds to an angular distance of 9 min. 45 sec.; hence, assuming the radius of the photosphere to be 426,300 miles, the depth of the solar atmosphere cannot be less than 255,000 miles. And, judging from the appearance at the period referred to, there can be little doubt that a larger and more perfect reflector will enable us to trace the spectrum still further down. Consequently, a further enlargement of the disc *f* will be required to extinguish wholly the reflected light from the solar atmosphere. It is reasonable, therefore, to suppose that the depth of the solar atmosphere will ultimately be found to exceed very considerably the foregoing computation.

It has been suggested regarding the instituted investigations of the radiant heat transmitted by the chromosphere, that the thermo-electric pile ought to be employed in combination with the parabolic reflector. The object of the investigation being simply that of proving by

the feebleness of the radiant power transmitted to the surface of the earth that the chromosphere and outer strata of the sun's envelope do not possess radiant energy of sufficient intensity to influence solar temperature as supposed by Secchi, tests of the suggested extreme nicety are not called for.

With reference to the effect of increased depth, the small amount of retardation suffered by the rays in passing through the highly attenuated atmosphere of the sun, previously established, shows that the question of solar temperature will not be materially affected, even should it be found that the depth of the envelope is greater than the radius of the photosphere.

THE STRENGTH OF MATERIALS.

From "The Engineer."

We have for years persistently put before our readers the fact that nothing is so much needed for the advancement of engineering science as experiment. A great Irish political leader of the people once made "Agitate! agitate! agitate!' his watchword. In like manner we use the word "Experiment! experiment! experiment!" Nothing can be added to our existing stock of knowledge without it, and those who experiment most frequently and most thoroughly best appreciate the value of the practice. In nothing are we more deficient than in our knowledge of the properties of iron and steel. We have much yet to learn about steam and the steam engine; about fuel, about boilers, about ships, roads, railways, bridges; about stone, timber, and cement; about, in fact, every subject with which an engineer, civil or mechanical, has to do. But about nothing are we more ignorant than of the properties and qualities of iron and steel; and it is not difficult to find the cause of this ignorance. It results simply from the fact that the varieties of iron and steel in the market are almost endless, and the processes of production are numerous and diversified, while the record of experiments made with the materials under different forms, and produced and used in different ways, are comparatively few and far between. On the importance of possessing accurate information concerning the properties of materials used in construction, we need not dwell. Every one admits it; but, unfortunately, the number of those who endeavor, by direct experiment, to increase their knowledge of the subject, is as yet extremely limited. This is not as it should be, and it is with a strict regard for the best and truest interests of science that we wish here to call the attention of our readers to the fact that in the heart of London there may be found a very modest establishment, conducted by a gentleman whose principal fault is that he refrains from putting his work more prominently before the eyes of the world, where more may be learned about the properties of iron and steel in a few hours than can be acquired by any amount of study, or by years of practice with these materials in construction. We speak of Mr. Kirkaldy's testing works in Southwark, and we propose here to say something of what Mr. Kirkaldy has done and is doing. Several years have elapsed since he published a treatise on the "Strength of Iron and Steel," which at once made him, in a sense, famous. His extraordinary care and foresight enabled him, with comparatively imperfect apparatus, to obtain a series of experimental results, which, in a manner, revolutionized existing theories on the subject. But the author of this work was not slow to perceive that, with improved appliances, he could extend his range of observation, and obtain still more valuable results. He spent two years in investigating the principles which should be observed in the construction of a thoroughly efficient testing apparatus, and two more in working out the details. The result may be seen in the magnificent testing machine at his establishment in Southwark. It forms no part of our purpose to describe this machine in detail. It will suffice to say that in order to get over a difficulty constantly urged against testing machines, to the effect that different apparatus gave different results, Mr. Kirkaldy designed a machine capable of breaking a heavy girder, or a ½ in. bar; of pulling asunder a thin wire, or the shank of a best bower anchor; of crushing a

great cube of cast iron, or a common brick, and yet in all cases giving results strictly comparable and accurate. This machine has been in constant operation for over 6 years, and Mr. Kirkaldy holds, in the light of the experience acquired during that space of time, that it is impossible to introduce any substantial improvement. As to its capacity for work, it will suffice to say that it can exert either a compressing or tensional strain of over 350 tons, with perfect safety. It will take in bars or columns of greater length than are generally used in construction, and it will test girders for transverse strain of any depth, and any length up to 30 ft., provided they are not more than 13 in. wide, measured across the flanges, the length between the supports while under test being 26 ft. The arrangements for measuring and recording the stretch and load on any specimen are extremely simple and ingenious, and heavy as the machinery is, the finish is so good, the knife edges so accurate, and the motion of the more massive portions so slow and so easy, that practically perfect accuracy is obtained.

But it is not our object so much to speak of Mr. Kirkaldy's testing machine as of the work he has done and is doing. Unfortunately, as we have stated, the value of his labors is not yet fully appreciated, and engineers and ironmasters are still slow to avail themselves of the facilities for acquiring information which he places at their disposal. Within the last few months, however, the Barrow Hematite Company, the Russian, and the Italian Governments have each put up a machine constructed under Mr. Kirkaldy's patents, but each only 1-4th of the power of the Southwark apparatus. Still this is a step in the right direction. We are happy to add that the Indian Government, alive to the advantages that can be derived from the testing of materials, have given Mr. Kirkaldy a contract for the examination of all the materials to be used on the new Indian railways. One of the first steps taken by Mr. Kirkaldy was to prepare a table for the Indian Government, in which various qualities of iron are classified under different letters. Thus, first quality iron must comply with one set of conditions, second quality with another, and so on. The Government have then actual figures to go on, the purchasers know what they ought to get, and the sellers what they are expected to supply, and no chance of dispute can arise. Thus, for example, plate iron in Class D must sustain a tensile strain of 23 tons per sq. in., and elongate 15 per cent. with the grain, and 9 per cent. across the grain. This is not a hard-and-fast rule, however, for if the iron broke with 22 tons, yet elongated 16 per cent., it would not necessarily be rejected. If, on the contrary, it stood 24 tons, but elongated only 12 per cent., it would not be considered to comply with the conditions. The first error would be on the safe, the second on the dangerous side. A glance at Mr. Kirkaldy's museum of specimens will show that the application of his tests has proved of the greatest utility. We shall not refer to any particular instances as regards the Indian railways, but it will prove interesting to give here a few examples of the work recently done by Mr. Kirkaldy and the results he has obtained.

A very large roof was not long since erected over an important railway station. The span is not much less than that of St. Pancras roof, but the construction is totally different, heavy wrought-iron flat tie bars being used to take the thrust of the principals. Nineteen samples of these links were selected at hap-hazard and sent to Mr. Kirkaldy to be tested. It was understood that the links were all to be of excellent iron. A proportion, however, of those tested were no better than puddled bars. It would be hardly fair to blame the manufacturers for this. No doubt they believed that they were supplying good iron, but such is the general ignorance of ironmasters of the properties of good iron, or the best methods of obtaining it, that, as we have said, bars little better than if they had been rolled off straight from the bloom were sent in. Of the many hundred tons used in the structure, of course the greater proportion must have complied with the specification; but the fact that even a few bad bars got among the rest shows how invaluable the system of test is. As an example of the value of practical tests, we may cite another instance. Two or three heavy links for the chains of a suspension bridge were recently tested by Mr. Kirkaldy. These had large flat eyes. In every case the iron, which was of fair quality, tore asunder through the eye; and a very simple calculation proves that these links, which

were designed by an eminent engineer, if strong enough in the eye, have no less than 18 per cent. too much iron in the body. When we consider the important part played by the chains of a suspension bridge, it will be seen that this error is one of enormous proportions, entailing great additional cost in the structure, and absolutely introducing an element of weakness in the shape of 18 per cent. extra weight, which it was highly desirable to avoid. If the designer of the links had taken the trouble to get half a dozen of various proportions made and tested, he would, at the outlay of a few pounds, have ascertained what was the proper shape to give his chain links, and hundreds, if not thousands of pounds would have been saved by the experiment. One more example of the value of such tests and we have done. A railway company, much troubled by the breakage of axles, ordered a lot of round charcoal bars, to get over the difficulty. These on examination did not appear of very good quality, and one or two, taken at hap-hazard, were sent to be tested. But a single experiment was required to prove that there was not a particle of charcoal iron used in carrying out the order if the sample was a fair specimen, as no doubt it was, of the lot. Here again we have a case where the outlay of a few pounds, beyond question, averted an accident which might have cost the railway company some thousands. Before leaving this portion of our subject we must narrate a little anecdote which Mr. Kirkaldy tells with no small humor. Certain individuals, who shall be nameless, applied some time since to the Government, stating that they had discovered a chemical process by which the strength of cast iron could be augmented 20 per cent. The authorities asked for proof, and referred them to Mr. Kirkaldy to supply it. So one day a cart was driven up to Mr. Kirkaldy's door, in which lay two bars of cast iron about 6 in. in diameter and a couple of feet long. The tensile strength of these Mr. Kirkaldy was asked to test. He was told all the circumstances. One of the bars was good ordinary cast iron, the other was made by the new process. The common bar was first put into the machine and broken; the results were registered. The second bar was then put in and the owners watched with anxiety till a similar strain had been put upon it. They then requested to be informed when a strain of 20 per cent. greater than that which broke the common bar had been reached. As the pumping went on, their excitement became intense; 15, 18, 20 per cent. was reached. The moment the latter point was attained they called on Mr. Kirkaldy to stop. This, however, he refused to do, notwithstanding frantic protestations on the part of the owners that they did not want their bar broken. Mr. Kirkaldy assured them that it was "a point of honor with him either to break any specimen put into his machine or the machine itself." In a moment more the bar broke. The section was remarkable. In the centre was a wrought iron bar about 2 in. diameter, and arranged near the edge were 6 ½ in. round bars all cast into the block, and partially converted into steel by the action of the hot cast iron! Of course the intention was to obtain a certificate from Mr. Kirkaldy that the improved (?) cast iron bore more than the common iron by 20 per cent. The breakage of the bar defeated the fraud. This strange story is literally true, and Mr. Kirkaldy has one half of the compound bar in his museum to verify its accuracy.

But it is not to be supposed that Mr. Kirkaldy's labors are confined to testing iron. His work includes every conceivable material of construction. His recent experiments with steel tires are especially valuable. It would be impossible, within reasonable limits, to detail these experiments, but we may mention one interesting fact. Some time since a steel locomotive tire broke, and a good deal of mischief was done. Small specimens cut from the broken tire were sent to him for examination. No two gave the same fracture, and the engineer of the line stated his conviction that the reason lay in some defect in the system of test. To this Mr. Kirkaldy replied that the true cause lay, not in the machine or system of test, but in the want of homogeneity in the tire, and he undertook to demonstrate this if he were supplied with larger test bars. This was done, and the facts came out exactly as Mr. Kirkaldy stated. We ourselves examined three broken specimens. One had a close tool steel fracture; another, a tough, almost fibrous, fracture; while the third specimen showed both, the line of demarcation across the bar being clearly defined. Here a very few experi-

ments proved beyond all question, to what cause the breakage of the tire was attributable. Mr. Kirkaldy has recently experimented with some very remarkable specimens of soft Bessemer steel made by the Bolton Iron and Steel Company, circular discs of steel $\frac{5}{8}$ in. thick and 12 in. diameter being forced through an orifice 10 in. in diameter into the form of a cup 3.38 in. deep, the pressure required to perform this feat amounting to 294,350 lbs., or 131.4 tons.

We have stated that Mr. Kirkaldy's experiments are not confined to iron and steel. He has, on the contrary, carried out some most valuable investigations on the strength of building materials, alloys, springs, india-rubber, tubes, malleable cast iron, belting, and ropes; but of these we cannot speak at present. We shall return to the subject. Meanwhile, we may add that Mr. Kirkaldy's museum is open to any engineer interested in the strength of materials; and we can assure our readers that they will find in its glass cases much food for reflection, and convincing proof that about the strength of materials we have one and all a great deal yet to learn.

WATER METERS.*

By F. E. BODKIN, Esq.

The question of measuring water supply by meter has for a great many years been occupying the attention of engineers. Ever since 1824 a yearly increasing number of inventions bearing upon this important subject, and amounting at the present time to a total of 313, have been brought before the public, in which are included patents taken out in England and communications from foreign engineers which have been registered at the Patent Office; yet, with all this great expenditure of ingenuity, it is generally allowed that there is no meter at present in really practical use which may be considered an accurate, or, in many ways, a satisfactory machine.

If we take a review of the time which has elapsed since 1824, when I stated the first patenting of a water meter is on record, we find that up to the year 1851, a period of 27 years, 30 different inventions had found their way into public notice; whilst during the 10 years succeeding, or up to 1861, no less than 90; and again, from 1861 to 1871, or the present time, 193. I do not mean to say that all these were for separate and entirely different machines; the larger proportion were so, but a great many only specify certain improvements in previous inventions, or apply them to particular uses, a process which frequently implies the production of a practically new instrument.

There could be no better argument than the above statistics found in proof of the general demand for a good water meter, since all invention is necessarily the result of some extensive public requirement. We may also adduce the fact that, unsatisfactory as are all the meters at present supplied to the public, they have, at least those amongst them which present fewest defects in working, met with liberal customers among the water companies and private individuals, who are willing, at much personal inconvenience and expense, to refer the estimate of their supply of water to the arbitration of these meters. In large factories, for instance, or in the case of machinery driven by water or steam power, and large stabling establishments, hotels, and even the better descriptions of dwelling-houses, it has been found an advantageous arrangement, and examples are enumerated by advertisers of water meters, pointing out the benefits likely to accrue to their purchasers, either on one side or other of the meters, from their use. For instance, a sum of £40 per annum paid in one case for water, rose no less than £1,000 in favor of the suppliers after the introduction of a meter. We may view the matter in another light, by comparing our dealings with water supply with our management of gas, not that the cases are in all respects similar, for gas is a luxury, hardly yet a necessity of life, whereas pure wholesome water is, in the truest sense of the word; but gas is, viewed scientifically, a very similar material to deal with, and is supplied by volume through pipes, and is turned on and off

*A paper read before the Society of Arts.

as required, and measured and paid for by meter. Moreover, by comparison of equal volumes, we find that water is the more expensive commodity of the two, which is an additional argument favorable to the use of water meters under certain conditions, even though there were more difficulty and expense in obtaining them.

If, instead of viewing the extreme cases I referred to above, we consider in a more extensive aspect the question whether the invention and use of a good water meter would be advantageous to householders and other consumers alike, one cannot but feel that the present system adopted for the general public, of payment according to the ratal or means of each separate consumer, is a most wise and liberal arrangement, hanging the chief burden of expense on the wealthier classes, and supplying an equal necessary of life to the lower orders at greatly reduced cost. Nor would the introduction of meters necessarily relieve any particular class, since the same expenditure would have to be defrayed as our requirements of proper purity and supply at present entail on the several water companies, whilst it would certainly act very prejudicially to the appearance and health of the "great unwashed" of our large towns, who would be only too anxious to reduce their water bills to a minimum. Perhaps, however, with the introduction of constant supply the general use of water meters might become an advantage—almost a necessity—to prevent waste; but in London, where this would be most severely felt, constant supply is, as yet, only a very remote possibility.

There are also other uses to which water meters may be applied, such as calculating the supply of water to steam boilers, for the purpose of ascertaining their evaporative power; also the expensiveness generally of water and steam power, a means of accurately judging which would enable the engineer, with far greater facility, to arrive at their comparative excellencies.

The great difficulties which surround the designing of a good water meter must excuse the ill success, so far, of inventors in meeting this demand; these may be better judged of by a short statement of some of the offices required of such a machine.

Firstly, a water meter should register with accuracy, that is, within 1 per cent. of the truth; and this, it must be remembered, not under a uniform rate of flow of the fluid, but under every possible variation of pressure—from a head only of a few feet, up to 200 or 300—unless, indeed, it be intended to act as a low-pressure meter, to some of which I shall call attention presently, and also under any ordinary variations of temperature.

Secondly, it ought to be of sufficient strength throughout to stand these high pressures, and even sudden alterations and blows under them, which form a still more trying ordeal.

Thirdly, it is very requisite it should be cheap, both in original cost and to maintain in repair subsequently. This latter consideration is very important, as under high pressures any bearing surfaces would be travelling at a great speed, and, even with the common impurities of water, would be liable to wear away very fast.

Fourthly, simplicity, both in number and shaping of parts, chiefly because all water meters are liable to get soon clogged with a muddy deposit, and require cleaning, and any complicity renders this operation difficult and expensive; it also naturally infers great costliness in repairs when the machine gets out of order, a defect to which such would be particularly liable.

It also often happens that a meter may be left unused for a time, and the working parts become dry. This should not interfere with the accurate working of the machine on its again coming into use; it is also greatly to the advantage of any meter that it should be uninjured by the entrance of heated water or steam, when supplying steam-boilers or other machinery, where such are used; that it should form a closed valve against the return of water already passed through it; also that the register and work should be out of reach of interference of people desirous to tamper with them; and, a very important consideration, that there should be as little loss of head or decrease of flow as possible in the water during its passage through. There are also peculiar excellencies, if we may believe the statements of advertisers, which recommend some meters for use in private dwellings, far in preference to others; for instance, a certain Frenchman, with the ardor of competition so peculiar to our neighbors,

describes his invention as not only a perfect meter, but a useful and elegant ornament for a gentleman's hall or drawing-room.

When we come to consider more carefully the leading features of all this vast mass of invention, we find that it is mainly directed to the measurement of water under two different conditions, low and high pressure; low pressure, where the water is delivered from the meter entirely free from momentum; and high pressure, where the water arrives at, passes through, and leaves the meter at the same, or nearly the same velocity. Low-pressure meters were in use some time before the introduction of the other description, are much more simple in design, and can be made to register with perfect accuracy, but they have now fallen into disuse, except in special cases, where a careful measurement, generally of some fluid more valuable than water, is required, irrespective of the time occupied in the process. It will be worth while to notice briefly the various ways in which this has been accomplished.

In the most simple method graduated glass tubes are used in connection with a barrel or vat, or closed chamber, and by which the amount of fluid run off can be easily read. Another, almost as simple, consists in the use of a measure-chamber in connection with an ordinary tap; the tap is at one end, and a valve at the other, or feed end of the chamber. These are so connected that one turn of the tap handle allows the water access to the chamber, and closes the outlet; the reverse action closes the inlet valve, and allows the measured quantity to escape for use; each turn of the handle is registered. The principle is applied in many ways, some constructing the measure-chamber large enough for a considerable supply.

A third makes use of a large vessel of known capacity, generally an upright cylinder, and places a valve on a properly fitted seating at the lowest part; there are also floats in the vessel, and while the valve is closed and the water rising, the float also lifts, and in doing so actuates lever arms, which by ordinary mechanism shift the valves when the vessel is full, the lower valve from its seating, and a cut-off valve attached to the inlet pipe. One means whereby this is attained is by hanging a weight from the float over a pulley, fixing a cam on to the shaft of the pulley, and causing the cam to raise a long lever arm at one point of its revolution. As the arm rises and falls, it moves the valve. The float when out of water, being heavier than the weight, falls with the water and reverses the valves at the bottom; a register tells the number of rises and falls that have taken place.

A fourth group of inventions places two tanks side by side, or subdivides one by a central partition; in each there are valves at the lower ends, and each contains a float. In one case a system of siphons is substituted, the supply-pipe is placed over the partition, and alternately made to direct its flow into one or the other subdivision; the float rises in each alternately, and, in most cases, by a central axis, which they actuate by lever, change the direction of inlet, and raise their own outlet valves; the central axis has weighted arms attached, to insure the instantaneousness of the action.

According to another device, a subdivided trough is centred on trunnions, and caused to tilt or tumble over from one side to the other by the weight of water which has flowed into each division of it from a fixed inlet; the trough is generally made triangular in section, and so proportioned and centred that it shall not tilt until each division is quite full; the number of tumbles is registered in this case.

A further modification of the above arranges a number of these tumbling buckets round a centre spindle, their continual filling and tilting causing the spindle to rotate. Sometimes they are made to work in a water level, each bucket gradually sinking down to it. But when fixed, free to revolve, they are arranged so that each weight of water must overcome the resistance offered by an arm of a weighted lever, which comes in contact with a catch attached to each bucket, and will not allow it to pass until out-weighted. The revolutions are registered, and represent in amount so many buckets full each.

A very novel idea is to measure, by means of a gas meter of ordinary construction, the amount of air exhausted from any closed chamber from which the liquid is allowed to run, the amount of water extracted being taken as equal to that of the air registered.

Endeavors have been made to convert several of the above into high-pressure meters, by making them of sufficient strength, and causing them to work without loss of head by air compressed in suitable chambers.

From this brief account it will be readily understood that water can be measured by low-pressure meters with the greatest accuracy, but they are entirely useless for supplying large quantities at any speed. They always require the intervention of a cistern of some considerable capacity placed high up; and in large establishments a separate meter would be required for every cistern. They may, in fact, be considered quite inadequate to the requirements of modern water supply.

Among high-pressure meters a greater variety exists; they may be divided into two principal classes, those which give a positive registration of actual quantities of water, and those which register by inference from the flow or pressure of the water passing through them.

Amongst positive high-pressure meters various arrangements of piston and cylinder hold the first place. The principle of these meters is to enclose in a hollow carefully-bored cylinder of known capacity a piston free to move from end to end by the pressure of the incoming fluid, the piston being caused by this force to drive out the quantities of fluid already measured. This motion, and its degree of perfection, will depend mainly on the arrangement of the valves which regulate the inlet and outlet of the liquid.

In the simplest form, the piston, very carefully packed, is fitted with a long piston-rod, protruding from a packing box at one end of the cylinder, and bearing one or two catches, which, just as the piston reaches the top or bottom of its stroke, come into contact with, or strike against, the ends of levers, causing the valves to shift; or the same is effected by a roller on the piston-rod running up and down in a slot in a bar of metal, and striking each end in turn; the bar, on receiving the blow, throws over a weighted lever, which alters the valves; or, by some, a rack is used attached to the top of the piston-rod; this gears with a pinion on a fixed shaft, two catches are fixed on each side of the pinion, and these alternately throw over a weighted lever from side to side; the weight in falling turns a four-way cock. This last is a device used by Mr. Kennedy, in his patent water meter, one of the first ever brought into use. It possessed the advantages over others of the same time, that it allowed a continuous stream of water to pass without serious loss of head, and registered very correctly. But the acknowledged defects of expense and great complicity, and also the continual attention required to keep it in working order, have caused its gradual fall into disuse; for it was found as soon as the oil in the works, which are not in these meters in contact with the water, got thick, the tumbling-weight refused to fall, and the water passed through the half-open valve without registry, and fresh oiling was found necessary every few months.

Messrs. Chadwick and Frost, in their Manchester positive meter, cut a long flat strip off one side of the upper part of the piston-rod; against this flattened portion a roller is pressed at the end of a bent lever, the square ends of the strip or slot drive the other end of the lever at right angles to the piston-rod, causing it to actuate in that line of direction a valve, which allows the water to flow alternately through the connecting link to the back of two small circular discs; its pressure at once forces each forward in turn, carrying the main valve with it, thus forming a fluid pressure valve. This arrangement is found superior to Kennedy's meter, and in fact has gained the ascendancy over all other cylinder meters we possess; but it is an expensive meter, and the number of wearing surfaces it contains prevent that durability which a high original expenditure ought to insure to customers. It will not either, without great additional outlay, stand exposure to heated water.

A French patentee specifies a long cylinder, containing two pistons joined by a rod, passing through a central division with bearings, on which the cylinder rocks by the greater weight of fluid alternately in each end, the central bearing being hollow and arranged on the four-way cock principle, and opened and closed by the tilting of the cylinder.

A large number of meters have also been devised, with two or more cylinders as measuring vessels; these are fixed side by side, fitted with pistons, and their rods working a common shaft by means

of cranks. By the revolution of this shaft two eccentrics or cams are made to open and close the valves; these are sometimes placed between the cylinders, sometimes on the outside, and in one case, in a meter designed by Mr. Duncan, placed at a considerable angle to the piston-rod. When the cylinders are placed in the same line, end to end, as is the case in some meters, the rod connecting the two pistons, by means of a long catch, is made to actuate bars placed parallel to the piston-rod and outside the cylinders. These bars move secondary valves, the primary valves being placed at right angles across the further ends of the cylinders, and driven by water pressure regulated by the secondary valves, thus forming a similar, but more clumsy, fluid pressure valve to that used by Messrs. Chadwick and Frost. In some cases the cylinders are made so as to slide telescopically on one common cylinder open at each end, with a central water-tight division; but in this arrangement the valves are a great difficulty, and the accurate fitting of the cylinders is expensive.

When the cylinders are set at an angle to one another, it is generally, as in an invention of Mr. Jopling's, at right angles, and the piston rod of one is made by direct action to open and close the valves of the other, the pair being closed in a water-tight casing.

An invention by Mr. Worthington, of the United States, consists in an arrangement of two cylinders, each containing two plungers or pistons connected by a single rod, bearing a central division plate. The valves are placed between the containing cylinders, and the alternate spaces are connected by crossway passages, from one into the other of which the water flows before it leaves the meter.

The chief object aimed at by the combination of several cylinders is a continuous discharge from the meter, and the prevention of any concussion occurring in the pipes. This is so perfectly effected by Messrs. Chadwick's meter that any additional complication and expense, such as these machines involve, is quite needless.

Another American method uses a cork piston or ram, packed with cupped leathers; and a Mr. Heppel furnishes a solid wooden cylinder, with an annular leather bag, and causes it to work loosely in a cylindrical casing. These have their advantages in cheapness and absence of friction, but their adaptability in continual contact with water is very questionable. The best form of piston for a water meter appears to be a cylinder of metal with a flange at each end, the intervening space being long enough to allow the travel of a rolling ring of india-rubber up and down during each stroke of the piston.

There is yet another combination of pistons and cylinders, which has been devised for measuring water. The inventor places a number of cylinders round a central shaft free to revolve, and attaches the heads of their piston rods to the corners of an inclined plate centred on the central shaft; the pressure of the water against their pistons causes them to rotate, and their revolutions open and close their respective valves. They may also be placed along a common trough or pipe, and their piston-rods in gear with a common crank shaft. They are free to oscillate, and, in doing so, valves at their junction with the main pipe are alternately open to each side of a central partition in it, which divides outlet from inlet.

The next description of positive meters includes all which are constructed to work with flexible or elastic diaphragms. The principle of these meters is, that a perfectly water-tight partition shall be formed, capable of assimilating itself to either end of a containing chamber, its edges being firmly bedded in the sides of the chamber, so that water admitted on either side alternately will force the diaphragm tight against the other. The shape of the chambers used to inclose these diaphragms is generally that of a double sector, or a sphere, or with inclined sides and flat ends. The chambers are most usually broad and shallow, and made of two shaped plates bolted firmly together, with the diaphragm between them. This is made of leather or vulcanized india-rubber, toughened by layers of calico or prepared cloth. It is generally strengthened by a central plate of metal, to which a piston-rod is attached, which passes out of the chamber and actuates the valves.

In one patented by Mr. Ramsbottom, in 1855, there are two diaphragms in doubly conical chambers, the rods of

which turn a common crank shaft. On this are two mitre wheels, which turn a rotary valve between them.

In a German meter, the rod actuates a lever with a chordal rack attached to the further end. This gears with a pinion, a crank on whose shaft moves the valves.

In another meter, four diaphragms are used at right angles, and all driving the same central shaft by means of cranks. From this shaft the registry is taken, and it is made to distribute through valves the supply of water to each pair in turn.

Meters of these descriptions will work with great accuracy whilst the diaphragm remains entire. But it has been found impossible to discover any material which will endure active work with certainty, and as soon as the smallest flaw occurs, water passes without registry.

Closely allied to meters of this description are those whose measuring chambers are made of compressible bags or cylinders. One of the simpler forms of these was patented in 1850. It consists of a water-tight chamber, containing two compressible cylinders, distended with metal rings at intervals. Their upper ends rise and fall vertically, as they fill and empty, raising and lowering each end of a bar with them. Chains from these ends pass over separate pulleys, and are attached to the ends of a cross handle of a four-way cock. Another design fastens two such cylinders end to end on a rocking arm passing right through them. They rise and fall as they alternately increase and lose weight, and alter valves seated at their point of connection.

Compressible tubes have also been often suggested as water meters; for use as such they are wrapped round a centre cylindrical core, or coiled in a ring on a circular plate, and a pair or more of rollers, revolving round a shaft placed in the centre of the bag, and pressing tight against it, are caused to move by the pressure of the water entering one end of the bag, and forcing the rollers before it, in order to escape at the other extremity. By the time one roller has arrived at the end of the bag a second comes into play; thus a series of waves of equal and known amount are continually passing through the bag and being registered by the central shaft. An invention of Mr. Siemens' makes use of a similar principle, by causing waves of liquid to pass down a tube of rectangular section, between the sides and a flexible central division. To all such meters the same objection holds as in the case of the diaphragm meter—that they are most uncertain in duration, especially if liable to stand idle, and their flexible portions to get dry and hard.

An entirely different description of meter are those which work on the principle of rotary force pumps or fans. They are usually made with cylinders or axes revolving either in the same centre or eccentrically in outer cylindrical casings with closed ends. The simplest form is that of a plate sliding in a hollow cylindrical shaft or an elliptical disc, sliding on a crank and revolving in an epicycloidal chamber, the inlet on one side, the outlet on the other. The fluid continues to flow, and the ends of the plate or disc cut off equal quantities of fluid, and register the number of revolutions. Or, the centre cylinder may be concentric with the outer casing, and have one or more flat vanes of metal let into slots in its periphery, which are forced into it at a certain part of its revolution, between the inlet and outlet holes, by a bulge or indent in the outer shell, causing the periphery of the inner cylinder to revolve in close contact with it, and forcing out the water included between any two of the vanes. These vanes are carefully packed, and must revolve in close contact with the outer circle; and for the purpose of always keeping them tight against this, a cam is placed inside the inner hollow cylinder, which forces them out at all parts sufficiently.

A French invention proposes to shut up air in the inner cylinder, and trusts to its compression and expansion to keep them in contact.

According to another, an eccentric axle is fixed inside the inner cylinder with four short arms; on to these are hinged the travelling vanes, which at a certain part of the revolution were required, bend at the hinges and recede, and afterwards again straighten and are forced forwards.

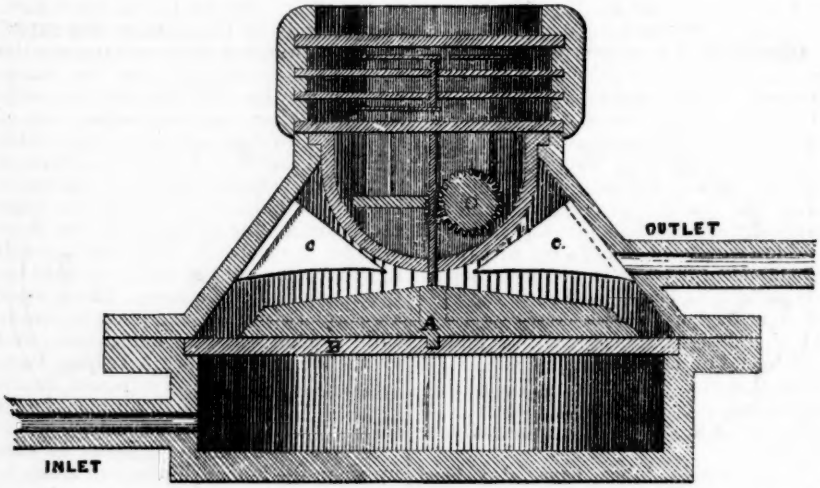
In these machines the accurate fitting and easy travel of the vanes is of great importance; but however carefully this may be carried out originally, from constant use these machines soon give signs of wearing and neglect to register accurately.

Some inventors make use of oscillating vanes or pistons swinging round in hol-

low cylinders from one side to the other of a fixed partition, the inlet and outlet being on each side and reversible by valves; and even more complicated arrangements of two or more swinging vanes, sometimes in adjoining cylinders, and other equally impracticable machines have been proposed.

A great many adopt the method of hinged vanes or floats, capable of laying close alongside their centre spindle, and of spreading out against the encasing cylinder under pressure of water. After the principle of the fan, the vanes are made concave against the pressure of the water, and are hinged on to a cylinder, so made to revolve eccentrically, that just before it reaches the inlet opening the blades are folded closely down, but on passing it they spread, and do not again close until they have passed the outlet.

Different arrangements of two cogged wheels, rolling in contact, have also been suggested; they are made of considerable breadth, and are placed in a double cylindrical casing, the one riding loose, the other fixed on a shaft which actuates the register. The teeth of such wheels must be very carefully made, in order to continue in contact at every instant of their revolution, the water being usually supplied immediately under the point of contact. It will be easily understood that the efficiency of the machine depends entirely on the good fitting of the gearing surfaces of the wheels, and which equally applies to the preceding description of meters, to the careful packing at each end of the drums. A meter which has not come into public use, but which has been found to work satisfactorily when applied to measure the water supplied to steam boilers, consists of a string of balls, fitting accurately in a loop formed in the supplying-pipe, and, passing over a pulley at each end, the water enters on one side of one pulley, and, carrying the string of balls before it, passes out at the other extremity. These balls cause the pulleys to revolve, and show how much water has passed.



Amongst inferential meters, which depend for their accuracy on their estimate of the velocity of the water passing through them, those which register the revolutions of an annular ring of metal, fitted with floats or paddles round its periphery, are most numerous; the water in this case being admitted through apertures as nearly as possible at right angles to the surface of the floats, impinges against them and causes revolution, but in a very irregular proportion to the speed and pressure of the water. An invention of Mr. Ramsbottom's has been used to some extent, and consists of a wheel with radial floats. Another machine, by Mr. Taylor, is very similar. He uses

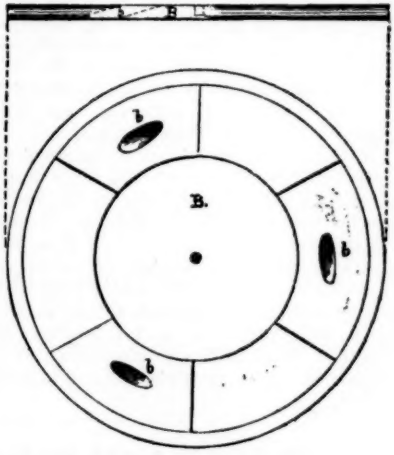
a horizontal wheel, provided round the periphery with radial floats, and riding on a vertical spindle in a closed chamber. It is to be made of any material of the same specific gravity as water, in order to reduce friction on the bearings, and is driven by the water admitted through small holes close to the wheel. This meter has been used considerably in the north of England, but is found much inferior in correctness and power of discharge to others.

To insure an even flow, which was the only condition under which these meters would work accurately, and to prevent low-pressure water from passing at all, several different methods have been devised.

By one arrangement the water is required to raise a clack-valve, held down to its seat by a delicate spring before it can impinge against the drum ; by another, the water is caused to pass through a contracted elastic orifice ; and by a third means, the flow of water in its action on the drum is regulated by a specially designed governor.

The next class of inference meters include all those which register the rotations of drums with screw blades fixed round them. These drums are fitted into long cylindrical casings, and the water flows past them, having first been directed through fixed guides turning in the opposite direction, and causing it to impinge on the drum-blades at nearly right angles. An earlier invention of Mr. Siemens' is of this description, who uses two drums, or two pairs of drums, turning in opposite directions, and set end to end in the same tube. The drums are made hollow, of a peculiar alloy, and have eight perfect screw threads passed round each. The registration is taken off the central ends of the drum-shaft by means of mitre wheels, and there are directing guides equal in number, but exactly opposite in direction, between each.

A patentee of 1851 places a similar drum, but rather longer, on a valve seating in a vertical pipe; it is thus rendered capable of lifting before any impurity which may be carried along with the



water. Some others use a great many series of drums and guides, and occasionally choose to admit the water without guides, simply between two reversed drums on the same spindle. The accuracy of these machines depends largely on the careful fitting and balancing of the drums, and their continuing to work without friction; but even under the most favorable circumstances they will not register with sufficient correctness at varying pressures, the error generally tending towards insufficiency at low pressure, and rising above the real amount at moderately high ones.

A further improvement has been suggested and used by Mr. Siemens and others, on the principle of a Barker's

mill, whereby the water is admitted into the interior of a chamber fixed on a spindle, out of which it flows by means of bent or curved hollow arms; the reaction of the outflowing liquid (for the vessel is entirely under water) causes it to rotate in an opposite direction; the spindle moves on a steel pivot encased in a water-tight oil-chamber; the water is admitted through a dirt-box; the revolving chamber is furnished with retarding vanes, and the upper end of the shaft has a worm-wheel attached which works the register.

The above meter has found most favor before the public, both in England and abroad, of all the meters yet introduced; but, notwithstanding its superiority, it possesses many defects. It is expensive, and is not by any means certainly correct under all pressures; it is, besides, so very delicate that it continually requires inspection and repair. It will pass water through at low pressures with a very insufficient registry, and will work backwards without difficulty.

A great step in the removal of all the above defects, both in this and every other meter yet introduced, is exemplified in an invention by Messrs. Cook and Watson—a meter which has only lately come before the public notice. It consists of an upper plate, A, indented on the under side, with a ring of thumb-holes, and riding loosely in a chamber over a lower plate, B, through which inclined inlet holes, *b*, *b*, are bored. The water rises through these holes, raises the upper disc, and acting against the square ends of the thumb-holes, causes it to rotate at the same time. This action of course requires some small power to commence, but as soon as the upper plate is lifted, it must also necessarily rotate. When the supply ceases, the upper plate falls, and forms a tight valve against the return of the water; and since during its period of revolution this plate floats in a film of incoming water, there are no wearing surfaces involved in the machine. Small arms or wings *a*, *a*, are placed on the upper surface of the revolving plate A, and also *c*, *c*, in order to produce regularity of motion under varying pressures, and appear, from the specimens I have at different times been able to test, to do so with complete success.

These machines are not expensive, and offer but small opposition to the flow of the liquid, and certainly appear to be *the simplest and most practicable form of high-pressure meter yet invented.*

A very different description of inferential meter consists in the use of a rod of alabaster, or other slowly soluble material, encased in a glass rod graduated, and at its lower end in contact with the running water. It is kept pressed down, and as it dissolves, the top descends and is supposed to denote the quantity of water which has passed. This seems very simple, but the readings must often be liable to considerable variation.

ON THE DENSITY OF WATER IN MARINE BOILERS.

Written for "Van Nostrand's Magazine."

The water used in a marine boiler usually contains a quantity of saline substances, the most deleterious of which is sulphate of lime; this is principally deposited on the heating surfaces of the boiler, when the water in the boiler can hold no more of it in solution.

The point of saturation varies considerably, decreasing as the temperature is increased, and increasing as the temperature of the water decreases; and as the temperature of saturated steam and the water from which it is generated, when they are in contact, are the same, the capacity of the water in a steam boiler for holding in solution the sulphate of lime in sea water, decreases as the temperature of the steam is increased; but as the pressure varies with the temperature—one increasing when the other does, though not in the same ratio the point of saturation of the water in a steam boiler decreases (holds less sulphate of lime or saline matter in solution) as the pressure of the steam in contact with the water is increased.

The pressure of steam in marine boilers has been increased within the past few years by the introduction of compound engines, using steam expanded tenfold, and even more, and economy in this kind of engine can only be obtained by

the use of steam of a high initial pressure, cutting off the admission to the cylinder at an early part of the stroke.

In this, as well as in the modern single cylinder engines, the surface condenser has been, and is still used to condense the steam after it has done its work in the cylinder, keeping the condensed steam apart from the condensing water, thereby making it possible to furnish the boiler with fresh, or partially fresh water, instead of the jet condenser, which furnishes feed water but very little less dense than the sea water.

It is well known that there is more power required to work the necessary pumps of a surface than those of a jet condenser, each condensing equal weights of steam ; this is a constant loss whenever the engines are used, and would amount in time to many horses power ; but in addition to this constant expenditure there is the difference in first cost between jet and surface condensers, besides the increased weight and wear of the latter over the former.

These are some of the disadvantages of surface condensers, and if they have so many, why use them? Simply, because we desire to have fresh water to feed to the boilers, and thus prevent this deposit of sulphate of lime, which has only about $\frac{1}{30}$th* of the conductivity of iron, and by this decreased conductivity, decreases the efficiency of the heating surface of the boiler.

The density of the water in a boiler is measured by a hydrometer, and when used to measure the density of salt water is usually called a salinometer; with it we do not measure the amount of sulphate of lime in the water, but the total amount of saline matter held in solution, the greater part of which is common salt.

Sea water contains about 3 per cent. of this saline matter, or 1 lb. in 32 of fresh water, and the hydrometer is graduated in 30 secs.; one being the density of sea water, and two twice that density, the marks on the stem of this hydrometer, if the stem be of a uniform diameter, are nearer each other between three and four, than between zero and one; this is accounted for by the increased density of the water, and consequently its increased buoyant power.

To illustrate this, take any body weighing 62.5 lbs., and 1 cubic ft. in volume; this will be equal in weight to a cubic ft. of fresh water, and will displace a cubic foot of water, and the body will be submerged; call this the zero point, increase the density or weight of the water from 62.5 lbs. to 64.5 lbs. per cubic ft.; then will the body rise out of the water and be but partly submerged, though it still weighs 62.5 lbs., and still displaces 62.5 lbs. of water. Now, if the body be wholly submerged it will displace 64.5 lbs. of water; but displacing but 62.5 lbs., which is equal to the weight of the body, it is but $\frac{62.5}{64.5}$ immersed; now, if the density or weight of the water be increased 2 lbs. at each trial, a cubic foot will weigh 66.5, 58.5, 70.5, etc., respectively; and the body will be immersed in the first case, in fresh water $\frac{62.5}{62.5}$ or unity ; in the second $\frac{62.5}{64.5}$; in the third $\frac{62.5}{66.5}$; in the fourth $\frac{62.5}{68.5}$; and in the fifth $\frac{62.5}{70.5}$; it is evident that the difference between $\frac{62.5}{62.5}$ or unity and $\frac{62.5}{64.5}$, is greater than between $\frac{62.5}{68.5}$ and $\frac{62.5}{70.5}$; this will account for the difference in the length of spaces on a hydrometer.

The usual practice of engineers is to carry the density of the water in the boilers at from 1 and $1\frac{1}{2}$ to $\frac{2}{32}$ secs., varying with the steam pressure, reducing the density as the pressure is increased; and to maintain a low degree of density of the water in the boiler, we must blow off a great amount of water, which has already absorbed enough of heat to raise it from the lower temperature of the feed water to the higher temperature due to the boiling point of the water under the pressure and density maintained.

The question naturally arises: at what temperature or pressure is all of this non-conducting substance, sulphate of lime, deposited, or at what density of the water? and are we blowing off from the boiler, water that is increased in density by salt or sulphate of lime? If there is no sulphate of lime in the water blown off, why not maintain the density of the water nearly up to the point of saturation with salt? If no more deposit of sulphate of lime will take place, surely there will be a saving of fuel.

In view of the unsettled point, as to what is the most economic density of water to maintain; and whether main-

* Some writers give it as much as one-sixteenth, and others as low as one-thirty-seventh.

taining high pressure steam in marine boilers (say from 60 to 80 pounds per sq. in.) occasions a greatly increased deposit of sulphate of lime, I would suggest that a series of careful experiments be made to determine the density that is most economical to maintain under different pressures of steam, making a chemical analysis of the water before entering the boiler, and of that blown off, determining the weight, thickness and quantity of scale deposited in each trial under different pressures and densities, in each trial evaporating the same weight of water, which should be determined by surface condensation in a continuous pipe.

The able paper of M. Cousté, "Annales des Mines," 1854, would be of much interest to any one making experiments on the incrustation of marine boilers, a subject which is of so much pecuniary interest to steamship owners throughout the world.

The following formula for determining the loss per cent. by blowing off was originated and much used by the writer some years ago, and has been found much simpler to explain than those generally given in the books, especially to a student.

The quantity of water entering the boiler is taken at unity; the quantity of water blown off, a fraction of unity, having for its numerator the density of the feed water in 30 secs., and for its denominator the density of the water in the boiler in 30 secs., unity minus the fraction representing the quantity of water blown off equals the quantity of water evaporated; multiply the difference in temperature between the feed water and the water blown off, which is also the temperature of the steam in contact with it, by the fraction representing the amount of water blown off; this will equal the quantity of heat lost or blown off; then multiply the difference between the temperature of the feed water and the total heat of the steam by the fractional part of the water evaporated; the product will equal the quantity of heat given to the water evaporated or the heat utilized; the sum of the heat utilized and the heat lost equals the total heat required of the fuel; then, as the total heat required of the fuel is to the heat lost, so is 100 per cent. to the loss in per cent.

This does not take into consideration the higher temperature of the boiling point of water by increased density, which is about 1.2 degrees for each 30 secs. per hydrometer.

Let d = density of feed water in thirty seconds.
D = " water in the boiler in thirty seconds.
t = temperature of feed water in deg. Fahr.
T = temperature of steam in deg. Fahr.
$1114 + .305\,T = H$ = total heat of steam in deg. Fahr.
$\frac{d}{D}$ = quantity of water blown off when the amount fed in is unity.
$1 - \frac{d}{D}$ = quantity of water evaporated when the amount fed in is unity.

$$\frac{100\left[\left(T-t\right)\frac{d}{D}\right]}{\left[\left(H-t\right)\left(1-\frac{d}{D}\right)\right]+\left(T-t\right)\frac{d}{D}} = \text{loss in per cent.}$$

J. C. K.

Almost useful work at Chatham Dockyard has now been completed—a tramway extending to most parts of the dockyard. It unites the various building slips, docks, factories, storehousés, etc., and also joins the Dockyard Extension on St. Mary's Island. As there are now very massive materials to move through the yard, this tramway will prove very useful. There are as yet no factories or storehouses on the Extension works, and the tramway will be found of great advantage in conveying materials, stores, etc., from the old dockyard to the new one, when ships are being repaired there. The tramway was formally opened on Wednesday by Captain W. C. Chamberlain, the Captain-Superintendent, who was accompanied by the chief officers of the yard. The party was conveyed in trucks over the various sections of the tramway, drawn by one of the loccomotives that is to be used on the line.—*Mechanics' Magazine.*

A method of imparting a yellowish hue to white marble is sometimes wanted. Dr. R. Weber has made known the fact that alcoholic solutions of perchloride of iron are not precipitated by carbonate of lime, and may therefore be applied in different degrees of concentration to impart a more or less deep yellow hue to white marble. The converse of this—the removal of yellow stains from white marble—is still a desideratum.

NOTES ON FIRE-PROOF FLOORS.*

The subject of fire-proof flooring can scarcely be treated under one head. For a floor might be, practically, fire-proof in a position where the heat is not likely to be great, whereas it would be useless otherwise. In the ordinary range of dwelling houses there is nothing to burn but the furniture and the timbers of the floors and partitions, mostly protected in part by plastering, and the heat given out is seldom enough to consume entirely even them. But in a warehouse stored with goods, which add to the mass to be consumed, the power of fire is shown in its most terrible form, and strong iron doors are crumpled up like paper. In a private house also, not only is there the advantage of there being less heat, but the floor-timbers usually bear at each end on a wall or partition. And even if the latter be of wood, it can easily be made almost fire-proof, either by filling in between the timbers, after the French manner, or with brick nogging and good plastering. But both must be carried up the whole extent of the partition, without vacancies between the floors.

By the modern plan of keeping the wall-plates out of the wall, the solid bearing is lost, and the wall-plate itself more exposed. The custom of carrying this plate upon stone or iron corbels is a bad one as respects fire ; for, though neither iron nor stone will burn, it will be shivered to pieces under the action of fire. A safe bearing can easily be obtained by forming oversailing courses of brickwork. No fire that I have ever known will destroy that.

In an ordinary dwelling-house, with plastered walls and no unusual amount of furniture, I look upon the plan of using wrought iron joists filled in with pugging, as being a good protection, provided always that the under sides of the joists are well protected by plaster. I consider, however, that a very thick layer of an ordinary pugging, filled in between wooden joists, would form as good a defence against fire, provided that the pugging could be combined in some way with the plastering of the ceiling, so as to form the two into one mass. The difficulty as to this, and it is one which I have not been able to get over, is that the fillets on which the pugging rests must be tolerably wide, and be kept some distance up the joists in order to prevent the latter splitting with the nails used for the fillets. Thus there is a space left between the sound boarding and ceiling too great to be filled in by the key of the plastering. This can be got over with iron joists, as the sound boarding can lay on their lower flanges. In case these joists are not used, I think that the best plan is to use pugging, say 3 in. thick ; to have the sound boarding in very narrow widths placed half an inch apart so as to let the pugging pass through the interstices, and then to render the under side of the sound boarding whilst the pugging is wet. But the boarding must, of course, be thoroughly dried, or as bad an enemy may be admitted almost as fire—namely, dry rot.

Before leaving the subject of dwelling-house floors, I must, however, call to your mind that the slight joists now used present very much greater facilities for destruction by fire than did the old heavy timbers formerly used. As architect to one of the chief insurance offices, and also to the London Fire Brigade, I have seen several thousand cases of fire, and it has been very rare, indeed, in the case of a dwelling-house, that a solid piece of timber has been burnt in more than an inch or so. A girder would be safe. But such an injury to one of our light joists would be fatal.

A few words may, perhaps, be devoted to staircases, though I am not sure that they come quite within the scope of my subject. But they are incalculably the most important part of the house as respects the means of escape, whilst they are, unfortunately, just the very part up which the flames rush with the greatest violence. In several damaged houses that I have seen, many of the rooms were scarcely burnt at all (the doors having been closed), whilst the staircase was utterly destroyed. It happens too, unfortunately, that this part of the building is, in our modern system of construction, the least protected. The wooden staircase is made with a thin-cut string, allowing full play for the flames against the end of the treads. The fire thus gets

* A paper read by Professor Lewis before the General Conference of Architects, 1871.

easily between the tread and the plaster soffit, and the utter destruction of the staircase is effected in a few minutes. Doubtless stone staircases are better than wooden ones; but I have seen even them repeatedly destroyed by being split by the heat and water, as in the case of a large house at the West-end, in which three people were suffocated. The stairs were of stone, and, very curiously, the landings were formed of ordinary wooden joists, with a thick ceiling of plaster. Every step, although of good solid Portland stone, was broken to bits. The wooden landings were absolutely uninjured. For safety, we must go back again to the old plan (for we are not quite so much wiser than our fathers as some think) and use thick close strings (protecting the sides of the treads), whilst the space between the latter and the soffit is filled with plaster.

The real difficulties of fire-proof construction begin where there is a large mass of combustible materials as in warehouses and similar structures. In these, the heat developed is something which an ordinary observer would scarcely credit. I exhibit some specimens of brass and iron nearly in a melted state, showing that the temperature which they had failed to withstand must have been some 2,000 deg. Fahrenheit. The whole place, in fact, must have been a glowing furnace. Now, to resist this heat, the use of timber is generally scouted as absurd, and reliance placed upon iron. This material no doubt will not burn; but from the specimens shown, you see that it will melt. Long before its melting point, the heated iron must have softened and lost its strength; and long before it began to soften it would snap asunder when chilled by the water dashed against it by the firemen. It is the latter risk that makes the iron construction so dangerous, and the boldest man in the brigade would hesitate to enter a building on fire whose supports he knew to be of iron. This risk is mainly owing to the exposure of the iron to the direct action of the flames, and it is curious that, almost without exception, what is called "fire-proof flooring" allows of this action. If that be the case, I know of nothing whatever that can save the floor.

In one of the warehouses burnt in the great fire in Tooley street, a different plan of iron fire-proofing had been tried on nearly every story. But each left the under side of the iron exposed. The result was a scene of utter destruction very difficult to realize. For the wreck is much greater where iron is used than where timber is employed. The iron expands and strains the walls; whilst wooden girders would leave them intact. I remember one striking instance of a factory which was very strongly built on a circular plan, the iron floor-girders radiating from a large well-hole in the centre. These girders of course expanded when the place was well on fire, twisted and broke the iron curb, and then pushed the walls bodily out. There must always be a likely chance of this occurring if any part of the iron be exposed. In such a case, and I say it distinctly, it will be safer to use thick wooden girders and brick arches than to turn these arches upon iron. It is not often that one has the opportunity of comparing the two materials, but I was enabled to do so in a large warehouse on Tower-hill. All the iron girders, though of sufficient strength, except in the case of fire, snapped in half. The wooden girder was burnt in for about an inch, but was otherwise intact.

It is difficult so to cover iron as to protect it, and many schemes have been devised for protecting it otherwise. The favorite one, no doubt, is to make the girders and columns hollow and fill them with water. This looks well in theory. But the ironwork must be *always* kept filled or it never will be so, when wanted; and there is then a very unpleasant risk of leakage. But setting that aside, if the hollow work be open to the air the water will soon be blown off into steam by the terrific heat generally attained; and if closed, the whole of the ironwork will soon assume the conditions of a steam boiler with its safety valves screwed down. I scarcely need quote examples to prove this. I have one, however, ready. At a large coal store on the Regent's Canal basin, the pipes of the hydraulic apparatus were full and closed. The cast-iron head, 1¼ in. thick, was split open from end to end and the pipe torn bodily out of it. All other attempts to protect iron efficiently have failed, as far as I know.

Iron may sometimes be made useful in a minor way. I once saw at Nottingham,

where much good work is done with Dennett's concrete, the ceilings of a factory formed of sheet iron. This is useless against a body of flame from below, but it prevents sparks dropping down from above. And as the floors are saturated with oil, this precaution has, to my knowledge, been of much value. But this is an isolated case, and I confess that as a general rule I see no way of using iron anywhere with success, unless every part is protected from the action of the flames. In fact, the result really seems to me to be that the only secure protection from fire is a structure of brick arches on brick supports. Nothing else that I can call to mind will stand the effects of great heat and the action of flames; stone and granite fly to pieces, but good brickwork never does. Perhaps the strongest case of endurance against fire known of late years was that at Tooley street, where an immense range of cellars was filled with oil, which ignited. For weeks this oil was burning—a rolling sea of fire. The cellars were vaulted with brick. They had this glowing mass below and the heated *debris* above, and yet after a careful scrutiny, when the oil was got out, I could detect scarcely a trace of injury. If this mode of construction cannot be used, I would trust strong wooden timbers thickly pugged and supported on strong wooden posts, in preference to iron girders on iron columns. But I cannot repeat too strongly, that, with a large mass of fire, no construction, under any circumstances, could be considered as really fire-proof, except solid arches on brick supports.

OBSERVATIONS UPON MAGNETIC STORMS IN HIGHER LATITUDES.

From "Nature."

The extension of the telegraph into the more northern latitude of the Shetland Islands, between 59 deg. 51 min. and 60 deg. 51 min. 30 sec. N., has afforded a much better opportunity of observing the frequency and variation of the magnetic and auroral storms that have of late excited some attention and discussion in these pages.

Some of the earliest recorded observations upon the strength and direction of these atmospheric storms, date from the time when the extension of the telegraphic wires over England rendered the phenomenon visible by the disturbance of the magnetic needle placed in circuit with the wires, and to a certain extent rendered possible the mapping down of the position and direction of the magnetic storm over certain tracts of Great Britain.

On the 24th September, 1847, remarkable magnetic disturbances were observed in London, and the direction and deflection of the magnetic needle noted. The effects of this magnetic storm were carefully observed at Dawlish, Norwich, Derby, Birmingham, Rugby, Cambridge, Tonbridge, Wakefield, Edinburgh, and York. The magnetic disturbance appears to have commenced about 1 h. 5 min. P. M. on the24th, and continued with variable intensity until 7 h. 30 min. A. M. on the 25th.

It may be interesting to give some of the galvanometer readings recorded as indicating the rapid oscillation and deflection of the galvanometer needle. In the period of time between 4 h. 17 min. P. M., and 5 h. 48 min. P. M. on the 24th, or in about one hour and a half, the direction of the current had changed no less than 10 times, showing a maximum swing of the needle over an arc of 50 deg.

H. M. S.	Deg.	H. M.	Deg.
4.17	15 left	5.5	15 left.
4.20	20 right	5.11	12 "
4.25	1 "	5.16	10 right,
4.25.30	18 "	5 22	18 left.
4.35	6 "	5.25	14 right.
4.38	12 "	5.28	13 left.
4.45	20 "	5.32	20 "
4.50	10 left	5 34	26 "
4 51	17 "	5 42	29 "
4.55	0 "	5.48	30 "
4 56	8 right		

During this magnetic storm, the variation of the dipping needle, which was observed in London every 30 min., ranged from 69 deg. 30 min. to 67 deg. 50 min.

In some cases these magnetic storms were so severe as to impede the working of the railway signals. On the 18th of October, 1841, a very intense magnetic disturbance was recorded, and amongst other curious facts mentioned is that of the detention of the 10.5 P. M. express train at Exeter 16 min., as, from the magnetic disturbance affecting the needles so powerfully, it was impossible to ascertain if the line was clear at Starcross. The superintendent at Exeter reported the next morning that some one was playing tricks with the instruments, and would not let them work.

It will be fresh in the memory of many of our readers that during the month of October, 1870, very remarkable and brilliant "auroræ" were observed in London, chiefly of a deep blood red color, spreading from the zenith over a great portion of the heavens.

It is, however, in the more northern latitude of the Orkney and Shetland Islands that the grandeur of these wonderful electrical phenomena can be observed, and that reliable data can be obtained from which hereafter some practical result may be deduced.

As observed in Orkney and Shetland, the aurora, as a general rule, appears to concentrate and emerge from behind a dense mass of dark cloud lying low down in the horizon towards the north. The edge of this cloud-bank is serrated and jagged, as if the mass were electrically in a high state of tension. From behind this cloud-bank "dark" streamers will appear to start up high into the zenith, appearing as if attenuated portions of the edge of the cloud-bank had been dragged by some invisible power, these dark auroral rays being at the same time transparent as regards the power of transmitting the light of the stars, which shone through with undiminished splendor. At the same moment that these dark rays are emicant, brilliant green, violet, crimson, and white rays appear to stream upwards towards the zenith, but always with a less persistence of duration. These colored scintillations change with greater rapidity than the black rays.

During the month of December, 1870, some very vivid prismatic tints were observed from the Island of Eday. From careful observation it was then remarked that the red colored rays appeared generally to be of a partially opaque nature, and it could be readily seen that the light of a star, when viewed through the red scintillation, was dimmed as compared with the brilliancy of the same star when observed through the scintillations of another color.

In some of these displays, the most vivid and varied coloring was exhibited. These were noted down as visible to the eye at the same time, and as the colors were observed in contrast, the distinctiveness and brilliancy of the tint became the more decided. Black, pale yellow, strong yellow, white, violet, pale blue, bright green, crimson shade fading into a reddish pink, pale orange, and a delicate sea-green tint. So far nothing approaching to the indigo hue has been noticed. With this exception, the entire prismatic colors and blending tints may be said to have been perfectly developed in the rapid electrical scintillations of the aurora. The colors fade away and change with astonishing rapidity, and this variation in tint will take place without apparently any great electrical disturbance in the special ray observed, beyond a slight flickering motion. In these regions, where the atmosphere is so perfectly still and at times calm, repeated observation has determined the existence of very appreciable sound to the ear, as an accompanying phenomenon to the rapid rush of the auroral streams towards the zenith. The intensity of the sound emitted varies considerably. At times, it greatly resembles that of the rushing noise caused by the firing of a rocket into the air when reaching the ear from a distance. At other times it has a strong resemblance to the sound produced by the crackling of burning embers, but wanting in any very distinctive sharpness.

In all these cases of auroral displays the inductive effects upon the telegraph wires are very strongly marked; currents of varying intensity and direction flowing unceasingly through these metallic circuits.

The result of observations made in Shetland during the months of September, October, November, and December, 1870, tend to show that these auroral disturbances attained their maximum effect upon the wires between 8 h. 30 min. and 9 h. 30 min. A. M., and between 8 h. 30 min. and 10 h. 30 min. P. M.; and such is the unstableness of these induced auroral currents,

that frequently in 5 min. the electromotive force will vary from very much less than that of a Daniell cell to a current of such intensity that a brilliant stream of light will flash across the points of the lightning conductors with sharp detonating reports, the electromotive force of which would be scarcely equalled by 500 Daniell cells.

In January, 1870, very curious electrical phenomena were observed at Lerwick through the day-time, in connection with the N. E. gales so prevalent at that period of the year. In Shetland these gales are almost without exception accompanied with very severe hail-storms. The day begins bright and fine, a clear sky, the barometer rapidly rising; low on the horizon may be observed dense and angry-looking clouds. One by one these clouds travel fast towards the zenith, when all at once a fearful gust of wind, accompanied with the most violent hail-storm, will apparently break out of the cloud, and continue for about 15 min. The wind then subsides, and the day appears as fine as before. In half an hour's time a second cloud will have appeared, and there will be a repetition of the temporary tornado and hail-storm. The remarkable circumstance attending these successive storm clouds is that they appear to be a purely electrical phenomenon. The moment that the icy discharge takes place from the cloud with its accompanying "crack" of wind, an induced electrical current appears upon the wire, so strong that it attracts firmly down the armatures of the telegraph Morse apparatus. The moment, however, that the hail ceases, the current passes off, but with this result, that each successive cloud storm appears to induce a current flowing in an opposite direction from the last, that is to say, the currents appear to be (using conventional language) positive and negative in their effects.

That these storms are "electrically excited" there is no disputing, and that they occur during the prevalence of the chief auroral displays is also a matter of observation; but so far their connection with aurora has not been sufficiently determined to permit any opinion to be expressed.

The recent successful completion of the telegraph circuit to Shetland, and the extensions immediately to be carried out 100 miles farther north, will afford much greater facilities for auroral observation than has hitherto existed. It is also proposed to institute a careful spectroscopical examination of the colored scintillations; and now that the Meteorological Society are about to establish an observation station in Shetland, there is every prospect of some valuable data being collected on this interesting subject, which may hereafter guide our meteorological students in arriving at some satisfactory conclusion regarding the laws of electrical storms and auroral induction. At present we are only able to record a few carefully observed facts.

THE FAIRLIE SYSTEM.

From "Engineering."

On a recent occasion we stated that the experiences obtained with the Fairlie engines on the Festiniog Railway, were only such as served to show on a small scale that which might be expected from the system when it received its full measure of development, and was enlarged from the minute 2 ft. gauge of the little mineral line, to the greater requirements of a heavy and general traffic on a broad gauge railway. At the same time we pointed out, that while to Mr. Spooner, engineer of the Festiniog Railway, was due all credit for the energetic and untiring manner in which he had always assisted in the development of the Fairlie system by affording to it the full use of his line, still the time would soon arrive when a larger and more important railway must become the testing place of the double bogie engine.

The recent experiments in Russia have fully confirmed this opinion, and although St. Petersburg is not so accessible as Port Madoc, it is to the former place that all interested in ascertaining the real capabilities on a large scale of these engines should for the present address themselves. Fortunately the performances are so minutely recorded, and are authenticated by such unquestionable authority, in the official reports, that the long sustained and persevering efforts to throw doubt

and discredit on the system during its earlier stages on the Festiniog Railway, may well be spared now that it has arrived at more mature growth. Possibly this may not be the case, for it is only a few weeks since, even while the recent experiments were proceeding with the utmost success, that an unfounded rumor was circulated that the Fairlie engines sent to Russia had proved failures. We say unfounded, because the only basis upon which this false report rested, was the fact, that on a recent occasion the Emperor of Russia inspected one of the engines recently sent out, and which was mismanaged for the moment by the men in charge of her.

The visit of the Imperial Commission to the Festiniog Railway led to the Fairlie engines being built for the Livny Railway, a narrow gauge line, 38 miles long, in the Government of Orel, Central Russia. The results obtained on the Livny Railway led to the adoption of the same system on the Tamboff-Saratoff Railway, a line 225 miles long, and opened in 1870. Again, the Grande Société of the St. Petersburg and Moscow Railway, desirous of satisfying themselves as to the real capabilities of the system, directed experiments to be conducted with two of the new engines, Nos. 5 and 6, which had been sent out for the Tamboff-Saratoff Railway.

The Count Bobrinski, now the energetic Minister, was, if not the first, at least an early advocate for the construction of railways in Russia. More than 34 years since, he brought about the construction of the short line from St. Petersburg to Tsarskoée-Selo, and urged the commencement of the railway from St. Petersburg to Moscow. This line, which was not completed till 1851, is a monument of autocratic engineering. Throughout its whole length of 400 miles it bears the mark of semi-barbarous extravagance. Its most remarkable feature is that it is without a curve for its whole length ; the Imperial command willed that it should be straight, and it was straight. But it has heavy gradients, and to surmount these, powerful engines, built by Cail and Débbs, have been employed, and these are only able to carry a very limited load ; to obtain engines capable of a higher duty is the object of the Grande Société working the railway, and with this view the Fairlie engines belonging to the Tamboff-Saratoff Railway were brought up to Malaia-Visheva on the Nicolai (St. Petersburg-Moscow) line, in order to test their capabilities.

The ruling gradient on this railway is 1 in 125, about 10 miles long, the remaining 390 miles having gradients not exceeding 1 in 500, and only a few short lengths with inclines of 1 in 200.

The construction of the Tamboff-Saratoff engines is similar to those working on the Livny narrow gauge railway, which were illustrated and described in "Engineering," of November 10th last. The Tamboff-Saratoff and the Nicolai Railways are built, however, on the usual Russian gauge of 5 ft., and the locomotives of which we are now speaking are heavier and considerably more powerful than those for the Livny line. Each engine is placed on 2 bogies, each bogie resting on 6 coupled wheels, 3 ft. 6 in. in diameter, and each having a pair of cylinders 15 in. in diameter with 20 in. stroke. The wheel base of each bogie is 8 ft., and the total wheel base of the engine is 29 ft. 3 in. The heating surface of the engine is 125 sq. ft. in fire-boxes, and 1,500 sq. ft. in the tubes, making a total heating surface of 1,625 sq. ft. The weight of the engine empty is 43 tons, in working order about 54 tons. The tanks are made to contain 1,800 gallons of water ; there is room on the engine for about 400 cubic ft. of wood fuel.

A couple of days before sending the engines to the part of the line where the gradient is situated, they were running about the stations, and the remarkable ease and steadiness with which these engines ran on curves, and over points and crossings, attracted much attention.

The two engines having arrived at St. Petersburg from Riga, they were dispatched to Malaia-Vishera Station, where the trials were to begin, and on December 1st a numerous party of engineers and gentlemen interested in railway matters, started with the trial train ; among these were General Kœnig, Director of the Nicolai Railway, Mr. Wall, Locomotive Superintendent of the line, and a few other engineers of the Grande Société. A commission of distinguished engineers from the Government Railway Department was also present.

The line from Malaia-Vishera to the Okoolooka station, a distance of 52 miles, begins with a rising gradient, averaging 1

in 240 for a distance of 22 miles; then comes the gradient of 1 in 125, 10 miles long, after which the road falls with an average incline of 1 in 240.

The trial train consisted of 45 4-wheeled loaded wagons, weighing 15 tons each, and 2 saloon passenger carriages, making a gross load of 705 tons, exclusive of the weight of the engine. The train started from the station with perfect ease, and at a very short distance from the station the speed attained was 13 miles an hour, which was maintained throughout except on the gradient of 1 in 125, where it was diminished to 10¼ miles an hour. About the middle of this gradient is situated a station, where the train is obliged to stop and take in water and fuel. This place is rather a trying point for an engine coupled to a heavy train, there not being any level place from which to start. Nevertheless, the Fairlie engine did its duty well, starting without the least trouble, and pulling the train to the end of the gradient without difficulty. Although the rails were in a miserable condition from the thawing snow, which had fallen all day, there was no slipping, and sand was not used at all. The engine kept her steam perfectly, the gauge marking only a difference of pressure from 130 to 140 lbs. The quantity of wood fuel consumed for the whole run of 52 miles was 502 cubic ft., and the lighting of fire and getting up steam required about 60 cubic ft. more. From the Okoolooka station the engine took back to St. Petersburg a passenger train, running on an average at the rate of 26 miles an hour, the speed being diminished in passing over the points, crossings, and bridges. In order to keep time, trains are obliged to increase speed sometimes to 30 miles an hour between the stations.

The performance we have just described is well worthy of being examined in some detail. Including the engine, the gross weight of the train was 759 tons, or 1,700,160 lbs., and on the gradient of 1 in 125 the resistance due to gravity alone would thus be $\frac{1,700,160}{125} = 13,601$ lbs.; and if we take the frictional and other resistances as averaging but 8 lbs. per ton for the whole train—a very moderate allowance—these resistances will amount to $759 \times 8 = 6,072$ lbs. The total resistances would thus be $13,601 + 6,073 = 19,673$ lbs. The average speed on the gradient is stated to have been 10¼ miles per hour, equal to 902 ft. per minute, and the effective horse power developed must thus have been:

$$\frac{19,673 \times 902}{33,000} = 537\tfrac{3}{4} \text{ horse power.}$$

This is probably by far the greatest horse power ever developed by a locomotive when running at the moderate speed of 10¼ miles per hour, although at high speeds it has been exceeded. Each bogie having a pair of 15 in. cylinders, with 20 in. stroke, and the wheels being 42 in. in diameter, the pull which the engine is capable of exerting for each pound of effective pressure per sq. in. on the 4 pistons will be:

$$\frac{15^2 \times 20 \times 2}{42} = \frac{225 \times 20 \times 2}{42} = 214 \text{ lbs.};$$

and the gross pull of 19,673 lbs. must thus have required a mean effective pressure of $\frac{19,673}{214} = 91.9$ lbs. per sq. in. on the pistons. This pressure could be easily obtained with the steam pressure maintained in the boiler. A point of great interest connected with the trial was the amount of adhesion found to be available. The experiment, it must be remembered, was carried on during a snow storm, and no sand was used, yet the engine did its work steadily without slipping, while the pull was equal to $\frac{19,673 \times 100}{54 \times 2,240} = 16\tfrac{1}{4}$ per cent. of the load on the engine wheels.

All the persons who assisted at the trials were highly satisfied with the performance of this engine; it was in all respects a complete success, and Mr. Fairlie, who was of the party, was warmly and deservedly congratulated.

The acquirement by the Grande Société of Fairlie engines to work the gradient on which the trial was made, will be highly desirable. At the present time the goods trains are worked on this part of the Nicolai line, as we have stated, by the Cail engines, weighing 44 tons in working order, with 8 coupled wheels, giving a total weight on the rail of 5½ tons per wheel, which occasions a great wear to the permanent way.

It is impossible to make a correct comparison of the consumption of the fuel between the 8-wheeled engines and the Fairlie engines, but undoubtedly the latter uses less fuel than the former in doing the same amount of work. Although these 8-wheeled

engines are very well built and do good work on the line, they are nevertheless not able to take on the gradient of 1 in 125 a train of more than 32 loaded wagons in summer and 30 wagons in winter, or a gross load varying from 484 to 516 tons. This is a serious obstacle for the successful traffic, because on the whole line, except these 10 miles of gradient, trains of 40 loaded wagons are easily worked by the engines now in possession of the company. This impediment can be overcome by adding a second engine to pull the train up the gradients, but it is more economical to use one engine instead of two, and this can be done by working that part of the line where the gradient is situated, by a Fairlie engine.

UNARMORED SHIPS.

From "The Engineer."

The construction of efficient ironclad ships presents a problem, the solution of which becomes day by day more difficult. The battle which has raged between guns and plates since Sir Joseph, then Mr., Whitworth, drove a shot through 4 in. of solid plate on the side of H. M. S. Alfred, in 1858, has for the present resulted in the triumph of the guns. It is certain that we have not a single ironclad afloat that cannot be penetrated by shot and shell at close range, while the majority of our ironclads are not invulnerable save at a range of at least a mile and a half. Such a thing as an absolutely impregnable ship or turret has at this moment no existence. Nor has anything like the limit of destructive power in our guns been reached. Recent improvements in the manufacture, and, if we may use the word, in the construction of gunpowder, have opened up quite a new field for progress, and enabled us to use with success charges of heretofore unheard of weight. The 35-ton gun is an accomplished fact. That it can be manufactured with certainty, and worked with efficiency, no one doubts. Mr. Fraser long since expressed his conviction that he could make a 60-ton gun which should be as successful as the largest gun then in the service, weighing 18 tons; and there can be no doubt that if he gets the chance he will keep his word, provided he is supplied with proper plant. In a word, although we already possess guns which laugh at the heaviest targets afloat, these guns are not nearly the most powerful guns it is possible to construct and to use. But how stands the case with our ironclad ships? The limit of thickness in plates which can be carried on any hull of reasonable size has been practically reached long since, and we have been compelled as a nation to reduce the area to be protected, by adopting the turret system and cutting down the freeboard of our ships of war, the Glatton representing the best that can be done in the way of combining defensive with offensive powers. Even though it were possible to coat our ships or monitors with plates which would defy guns used in the ordinary way, we should be as far from the desired end as ever. A new danger, which, beginning like a cloud as big as a man's hand, has gradually loomed up till it covers the whole face of the sky, has to be dealt with. The torpedo has risen from the rank of a scientific toy to that of one of the most powerful implements of naval warfare, and no one in his senses can doubt that but little stimulus is required to inventors to set them at work improving on existing designs and scheming new ones, with the result, and that not a distant result, of rendering the torpedo the most deadly enemy of an ironclad fleet. Nor does the force of the attacking party terminate here. There is yet another danger to be dreaded by the ironclad, namely, the action of submarine ordnance. A gun of very moderate size fired under water would at close range punch and send to the bottom the strongest ironclad we have afloat. The experiment was tried years ago with the most perfect success—a success so great, indeed, that it is only matter for wonder that the experiments were not continued.* Thus it appears that our best ironclads can be penetrated by shell both above and below water, while these are liable at any moment to have great chasms

* Vide Evidence of House of Commons Committee on Ordnance, 1863, page 107.

blown in their bottoms which would send them to the bottom almost in the twinkling of an eye. We are not alarmists; we do not wish to make facts appear worse than they are; but we venture to say that there is not a reader of this journal in existence possessing a competent knowledge of the subject, who will not admit the accuracy of our statements and the truth of the deduction which we draw, to wit: That armor plating totally fails in the object for which it was intended. It can secure the safety of either crew or ship only for such a time as an enemy refuses to avail himself of the means of attack placed at his disposal by modern science.

Is it not time for the shipbuilder and the designer of ships to pause under these circumstances and set their houses in order—to consider whether there is not a way of escape—to determine whether it is or is not possible so to design the fleet of the future, that if they cannot defy the gun and the torpedo, they may at least render them as powerless as possible? The problem is enormously difficult, but, within certain limits, it is not, we think, absolutely impossible of solution. The solution, we believe, will lie, not in the extension of armor practically useless, but in the abandonment of armor almost altogether, and the construction of a different type of ship from any of those now in fashion.

As regards the attack of guns firing shells, it is obvious that unless armor keeps out such projectiles altogether it is worse than useless, simply because it renders the explosion of shell a matter of certainty. If ships were constructed with very thin and tough upper works, they would offer so little resistance to shells without fuzes, that the shell would pass in at one side and out at the other without exploding; of course the projectile would carry ruin in its track, but then its track would be so limited that the ruin would be of little moment. Ironclads cannot mount many big guns, and, as a consequence, the effect they would produce on an unarmed foe, by even a prolonged cannonade, would be less than that done by one of our old 120-gun ships in a single broadside. It will be urged that percussion fuzes would be used; but the percussion fuze for big shell is still a very imperfect affair, and the chances are that a large proportion of the shells used with such fuzes would either explode prematurely or not at all; in any case, nothing is gained in this respect by the use of armor. On the other hand, the suppression of armor plates would enable us so much to augment the engine power and coal space of our ships that they might maintain an unparalleled speed for days together, while they might carry guns of enormous power. Under these circumstances they could simply set torpedo boats at defiance; they could choose their own distance and keep just so far out of danger as they thought proper, disabling an enemy with their great long-range guns, while he would be powerless to inflict any injury. It is useless to urge that the enemy might be not only armored, but fast, and provided with big guns as well. This is impossible; we cannot combine immense speed, heavy armor, and huge guns in the same hull. We have not a ship afloat, which could not be defeated by an unarmored man-of-war capable of steaming 17 knots, and mounting a couple of 50-ton guns of sufficient length to enable them to burn all their powder in a bore of moderate diameter.

As regards torpedoes anchored, there is not so much to dread after all as some people think. It is known that the range of the torpedo is very limited, and the use of booms and torpedo nets would probably allow any fleet to pass without much loss through a channel protected with torpedoes alone. In any case, the unarmored ship would be quite as well off in this respect as the armored ship. The floating or missile torpedo is the really dangerous weapon; and the best protection against this engine of destruction is probably great speed in the ship attacked. But the unarmored vessel has further an element of safety at her disposal which the armored ship cannot have. There is so large a margin of buoyancy left at our disposal by the suppression of the plating, that it becomes easy to divide the whole bottom of the ship into numerous watertight compartments. A vessel built as it is quite possible she could be built, might receive the attacks of even 2 or 3 torpedoes with comparative impunity, while an ironclad—and especially a monitor—would go to the bottom like a stone.

All things considered, we believe that the day for ironclads has passed away.

That a few will still be used for attacking ports and defending harbors, is almost certain, but these ironclads will not be in any sense sea-going ships. The ocean battles of the future will, for anything we can see to the contrary, be fought by ships as free from armor as a Cunard steamer. The moment it is demonstrated that armor will not absolutely repel shot, it must be regarded as an objectionable incumbrance. So long as it really fulfils the purpose for which it is intended, it confers advantages which are worth obtaining, even at the sacrifice of almost every other qualification a ship of war should possess, except the power of fighting heavy guns; but it has been proved, as plainly as any fact can be proved, that such armor as a sea-going ship can carry, will not keep out the projectiles of guns of even moderate power, while it leaves the whole question of dealing with submarine attack absolutely unaffected, except in so far as it is a positive evil.

PRIVATE GAS MANUFACTURE.

From the "Journal of the Society of Arts."

One of the latest inventions for the purpose of enabling small consumers to manufacture their own gas, is that of Mr. Symes, who specially claims for his apparatus that it affords an opportunity for almost everybody to make their own gas. He claims, where the consumption is that of 25 lights, that his Patent Portable Gas Apparatus gives the consumer the power of making his own gas at a cheap rate. The first cost of the apparatus, from 25 up to 30 lights, is said to range between 20 and 25 shillings per light, the rate decreasing with every increase of light. Made from "slack," the cost of the gas is reckoned at a shilling per 1,000 cubic ft. Made from coal at 18s. per ton, with 10 per cent. of cannel, the cost is given at 2s. 2d. per 1,000 ft. The illuminating power is reported as equal to 18 candles or more, while the purity of the gas is stated to be perfect. At a recent trial, the gas was produced in a small iron retort fitted into what resembled an ordinary stove, the fire which heated the retort being also available for ordinary domestic purposes. A boy shovelled in about 3 lbs. weight of rather indifferent coal, and the door of the retort was then closed, fitting gas-tight into its place without any ceremony of "luting," that is to say, without any plastering up of the door of the retort to prevent the escape of gas. Within a few seconds from the closing of the retort, the gas began to flow out of the burners, and burned brilliantly, the number of the flames being increased as the coal underwent distillation. It is not absolutely necessary to use coal, or coal alone—bones, wood, or peat, being available. Peat, however, gives a weak gas. On its way from the retort to the burner, the gas passes, first of all, through water, which deprives it of certain impurities, after which it enters a condenser where the tar accumulates, and from whence this material can be readily drawn by means of outlet pipes. At the foot of the condenser is the purifier, and thence the gas proceeds into the gasholder. The space occupied by the apparatus is very moderate, the bulk depending mainly on the size which is thought desirable for the gasholder. The erection of the affair is within the compass of an experienced gasfitter. The process of manufacture is so automatic that a domestic servant once instructed could manage it with quite as much facility as the machinery of a kitchen range. All the solid refuse of the house which happens to be of a combustible character may be turned to account. The design of the invention is to provide individuals with a supply of gas where the smallness of demand precludes the operation of a regular gas company. Mr. Symes is also prepared with a modification of his apparatus for use on board ship. The following is a technical description from the specification of the patent, the purpose of which is the supply of cheap and pure gas to churches, hospitals, private houses, shops, offices, warehouses, factories, and other buildings, as well as to steamboats, railway carriages, signal ships, lighthouses, etc. As to the generation of gas, it is preferaple to do it from wood; but coal, paper, peat, resin, "dead oil," and, in fact, almost any material may be used.

It should be distinctly understood that no part of the invention relates to the use of any particular substance or compound for producing the gas or for burning wood, etc. The apparatus is provided with a circular box or retort of iron, or other suitable material, which may be placed in a kitchen range, or in any ordinary stove. The form of this box or retort allows it to be surrounded by the fire, and quick and economical production of gas is thereby obtained. The box is perfectly closed by a cover, fitted with a face like a valve, instead of being made tight by means of lime or cement, as in ordinary gas retorts. The retort is connected by a pipe or tube to a hydraulic main, which may be placed in the chimney, or arranged and supported in any convenient position in or near the house or structure. This vessel is partially filled with water, and the pipe or tube which connects the retort with the hydraulic main has one opening above the water, and another below the surface. The hydraulic main is provided with a safety valve, and when the pressure in the retort rises above a certain degree, the safety valve is forced open, and the gas escapes into the chimney, or into a pipe or passage leading thereto. Except when the safety valve is open, the gas leaves the pipe through the opening below the water level, and the apparatus will thereby work with a pressure considerably less than if the gas entered the main above the water. The exit pipe for the gas is at the top of the hydraulic main, and the tar pipe is at the end or side thereof, level with the surface of the water. The main is provided with a covered aperture for pouring in the water, and with a tap for permitting it to escape. By this means the level of the water in the main can be so regulated as to insure the continual proper working of the apparatus. The gaseous products of combustion received from the retort into the hydraulic main are by the latter separated, so that the gas passes away through the exit pipe, while the tar and other impurities, except the sulphur, are carried off by the tar pipe, which terminates in a larger tube, or cylindrical vessel, arranged below the main. The hydraulic main is connected by the gas exit pipe to a condenser, which is a vessel having within it a series of vertical partition plates, so arranged that the gas passes alternately over and under the other until it leaves the condenser. The latter is connected to a purifying vessel, which is divided vertically into two chambers, in one of which there is a series of sieves containing lime, and in the other similar sieves, with sawdust, sand, or other suitable material. The gas, as it enters the purifiers, passes up through the lime, and enters the second chamber, and descends through the sawdust, thence passing, free from sulphur, away through the pipe to the gas-holder. This gas-holder is preferably a cylindrical vessel, which may be made of sheet iron, zinc, etc., and is partially filled with water. It may be made of any required capacity. Inside the gas-holder is an inverted chamber, which opens into the water, and which rises and falls in proportion to the quantity of gas in the holder. At the top this interior vessel is provided with a small tube, which passes through a guide at the top of the holder; it has also a burner attached, whereby the quality of the gas in the holder can be tested at any time. Instead of using a cylindrical metal gas-holder, an air-tight bag, made of india-rubber, gutta-percha, leather, or other flexible material, may be used. In cases where it is desirable to increase the brilliancy of the light, a small carburetting vessel may be provided, this being partially filled with undistilled naphtha, or other carbonaceous liquid; the gas passes from the gas-holder in the vessel, where it absorbs carbon, and consequently increases the power and brilliancy of the light.

SOONER than was expected, a commencement has been made in filling the new factory basin at Chatham Dockyard Extension with water, which is admitted by culverts from the first or repairing basin. There is already a good depth of water in the new basin, but it will be some time before the full depth of water has been admitted. There is still a good deal to be done at the works. The third or fitting-out basin will not be completed for a long time; factories and workshops are to be erected, and two docks abutting on the repairing basin, are to be completed. In spite of some delays caused by irruptions of water and the troublesome nature of the soil, these docks are now well advanced.—*Mechanics' Magazine.*

PRE-HISTORIC FORTIFCATIONS.*

By. Mr. LAWSON TAIT.

Mr. Tait, after some introductory remarks, observed that weapons began to be used before any definite scheme of fortification came into use. The use of the stick or the sharpened stone commenced at a much earlier stage of the history of armature than the use of fortifications. The first indication of fortification was what they might naturally expect, viz., a fortified hillock, men finding that upon an elevated position they had an advantage in the use of their weapons. Thus they found that the earlier fortifications were hill forts. The well-known Roman forts with which this country abounded were not such as he classed amongst pre-historic fortifications, because pre-historic meant such as they had no historic knowledge of. In the earliest times, he believed that the structures of which he was going to speak were not intended for permanent residence, as forts now were. The huts of the village were generally on the outside, at a short distance from the fortified hillock. There was one instance in which the huts were inside the fortified enclosure. The lecturer then proceeded to make some remarks upon the fortified rock at Rhun in Strathfleet, Sutherland, which was the earliest type of any he had been able to see. So skilfully was this fortress constructed on the hill that its existence was never discovered until a sportsman shot a bird and saw his dog disappear over the rude wall which surrounded the enclosure. This fort simply consists of a space in the top of the rock enclosed by walls, the doorway being on the side which was most accessible. When there was an alarm the people from the village probably went into the enclosed space for protection, but it was evident that such forts were not intended for long occupation, as there was no place for the stowage of provisions. In those days, however, warlike incursions must have been of short duration. They came to other fortifications of more definite arrangement. The fortified rock in Sutherland, to which he had called their attention, and of which there were other instances, evidently belonged to the stone period—the period when men had to use stone arrow heads, stone hatchets, and stone hammers as weapons. The structures of which he spoke might all be relegated to the stone age, for although in some cases two or three small bronze implements had been found in them, they were of such kind as to lead them to the belief that these were there through accidental circumstances. There was no doubt that these structures were after the stone age occupied by men of the bronze age, as they were handed down as national property. After the enclosures, which were simply surrounded by a wall, they came to structures which were evidently intended for more permanent residence, there being chambers for the storage of provisions. These chambers were of great interest, as they showed that the people who made them had taught themselves how to form Cyclopean arches, which were not confined to Greece. In the first instance, there was was only one chamber in the structures, and this chamber was always on the same side of the doorway. This single chamber, he thought, was made to contain the rubble required for fastening up the doorway when there was an attack. The other and more extensive chambers were, however, undoubtedly for the storage of provisions. In one of the chambers in one of these structures in Sutherland the skeleton of a man was found, and amongst his bones was found a "quern," or grinding mill, and in it some grain. Mr. Tait then pointed out that the fortifications were placed in such positions that the people could carry on a system of telegraphy. So nicely had they been arranged that he had been puzzled to discover the two corresponding towers, until he had got upon the elevation, which exactly corresponded with the original height of the tower. The amount of surveying the people must have gone through certainly must have entailed great labor. After speaking of several pre-historic remains to be found in various parts of the country, and illustrating his remarks by reference to a large number of diagrams, Mr. Tait called attention to the fact that no one had "taken up" the pre-historic remains in Warwickshire, and then made some remarks upon the mound which they

*From an address before the Midland Institute.

saw at Brinklow during their excursion. He said his impression was that there was no fortification at that place which belonged to either Saxon or Celtic times, or was entitled to rank as of great antiquity. He thought the fortifications there were too extensive and too well done, and had none of the marks of the ancient fortresses to which he had drawn attention. If there were any they had escaped his notice.

RECENT PROGRESS IN MECHANICAL ENGINEERING.

From "The Engineer."

In mechanical engineering it is but right that the first place should be given to the steam engine. As regards the past year, it may be stated with perfect truth, that no improvement whatever has been effected in steam machinery. This may appear to be a very sweeping assertion, and it is therefore necessary to explain our meaning as precisely as possible, to avoid any misapprehension. What we intend to convey is that the most economical engines built during the year are not more economical than engines built long since; but it is probable that a greater number of really excellent engines have been built in 1871 than were ever constructed in any previous year. This is, of course, in a sense, progress, but it is not progress in the highest and truest sense; and it is worth while to place a few facts concerning the theory of the steam engine in a proper light, in order to show in what direction we must seek for improvement.

In the first place, then, it is impossible to take up a good text-book on the steam engine without finding a more or less elaborate "theory of the steam engine" enunciated; nevertheless, we hold that something concerning the true theory of the steam engine has yet to be decided, and we base our belief on plain facts. All the knowledge which we possess of the properties of steam, the laws of expansion, liquefaction in doing work, condensation, etc., is founded upon the investigations of a very limited number of experimenters, among the most important of whom may be named Regnault, Fairbairn, Tate, and Unwin, Siemens, Dulong, and Petit, and a few others. All the experiments conducted by these gentlemen were performed in the laboratory, or at least on a very small scale. The results they obtained have formed subject-matter for elaborate disquisitions by numerous mathematicians, who have supplied the world with plenty of numerical examples of the work which ought to be got out of a given quantity of steam. One of the best treatises on the steam engine that has ever been published* lies before us. At p. 33 we find a table showing the number of pounds of steam required to produce 1-horse power according to theory. The figures are as follows:

Pressures in Atmospheres.	Condensing.	Non-condensing.	Temperature.
	lbs.	lbs.	
2	11.2	50.4	249
4	9.2	24.8	291
6	8.3	18.9	318
8	7.7	15.9	340

In the case of the condensing engine it is assumed that the feed is thrown into the boiler at a temperature of 100 deg., and in the case of the non-condensing engine that it is introduced at a temperature of 212 deg., derived from the exhaust steam. We have every reason to believe that these figures are quite correct; it will be seen that they refer to the quantity of steam passing through the engine, and they have nothing to do with the efficiency of boilers or of fuel. Now as a matter of fact, in practice no engine in existence gives out anything nearly approaching this result. There is not, and never has been, an engine constructed, which, with any pressure or rate of expansion, has developed 1-horse power by the use of 11.2 lbs. of steam. It is quite true that, as Mr. Cotterell very properly points out, one main cause of the difference between the results obtained in practice and those which in theory ought to be had, lies in the fact that we cannot carry expansion sufficiently far to reduce theory to prac-

* "Notes on the Theory of the Steam Engine," by F. H. Cotterell, M. A. London: Spon. 1871.

tice; but this being granted, there still remains a large margin of wasted efficiency to be accounted for; and an explanation is also required of the reasons why expansion cannot be carried far enough. As to the first point, it will suffice to point out that if a steam engine working with 8 atmospheres—or say, in round numbers, 120 lbs. on the sq. in.—will in theory give a horse power for every 7.7 lbs. of steam passed through it per hour, we might expect that in practice it would perform as well as a theoretical engine working at a pressure, in round numbers, of 30 lbs. per sq. in., and so give out 1-horse power for every 11.2 lbs. of steam going through it per hour; but, as we have said, such a result has never been obtained from any engine in practice. As regards the second point—that is to say, the limitation of the degree of expansion—information is required as to the limiting causes. It will not do to urge that they originate in the difficulty of getting machinery to stand a high initial strain and to maintain an invariable speed. It has been proved that long before the limit is reached in this direction economy ceases, that is to say, nothing is gained by expanding steam beyond a certain point, and this point is reached long before much trouble is incurred from irregularity of action due to varying pressure; and this, strange as it may seem, holds true whether the cylinder is jacketed or not. The fact is that the experiments carried out with so much care and skill in the laboratory, do not apply accurately to the case of the steam engine in which enormous volumes of steam are used; and, as it has been pointed out before this, it is quite possible that the results obtained in the laboratory are vitiated by the small dimensions of the apparatus employed. Not a single instance can be cited in which the results of elaborate experiments with steam engines of considerable dimensions tally even approximately with the laws laid down in text-books. Either the laws are erroneous or there is some peculiarity about steam which causes it to differ much more widely than is generally believed, in its behavior, from that of a permanent gas. Lest it should be thought that in saying this we speak "without book," we may cite a few facts to which our readers will attach the importance they deserve. Mr. Isherwood, while chief of the United States Bureau of Steam Engineering, carried out an elaborate and exhaustive series of experiments on the use of steam in various ways. We have before now had occasion to criticise Mr. Isherwood's theories; but it is next to impossible to dispute some of his facts. One of these is, that by using superheated steam he obtained a large measure of economy, saving something like 30 per cent. in fuel; but he also found that if when using saturated steam with a certain measure of expansion, and without expansion, the difference in the total cost per horse-power was a certain percentage in favor of expansion; then when he used superheated steam in the same way without expansion and with expansion, there was a difference in favor of expansion, but this difference was precisely the same, whether the steam was or was not superheated. Now, seeing that superheating prevents condensation in the cylinder, and that cylinder condensation is the great enemy of expansion, it seems to be clear that the comparative efficiency of the steam—in other words, the economy of fuel—should augment as the expansion increases, in the case of superheated steam; but, as we have said, no such result was obtained. If this were an isolated case we might reject it; but we can produce corroborative evidence from a totally different quarter. MM. Nolet et Cie., of Ghent, have for many years been celebrated as successful builders of engines for driving cotton mills with extreme economy. Within the last few days we have been favored with a letter from M. Nolet, the contents of which we do not feel ourselves at liberty to make public. It will suffice to say that M. Nolet carried out some time since an elaborate series of experiments to test the value of the steam jacket. The results at which he arrived satisfied him that there is no advantage to be derived from the steam jacket, and that, further than this, his engines without the jacket are more successful than those with it. With or without, the engines rank among the most economical in existence; so that it cannot be argued that they were such large coal consumers from other causes that a jacket here or there made no difference. We may also point out that we have received letters from one of the most influential builders of compound engines, stating that the results obtained

at sea when steam was shut off from the jacket differed very little indeed from those obtained with steam in the jackets as regards economy of fuel. One leading mechanical engineer, building compound engines for ocean steamships, regards the jacket as an unnecessary refinement. In the case of the Cornish engine, jacketing the lid has been abandoned, because the saving in fuel due to its presence was not found to be worth the trouble of making and unmaking a joint every time the lid had to be removed; and, finally, we may point out that the large cylinders of compound engines are rarely jacketed, as it has been discovered that little or no condensation takes place within them, although they are exposed to the full action of the condenser, and present the largest surface to steam of the lowest pressure.

It may be urged that in writing thus, we are inconsistent; that we have recently devoted much space to maintaining the value of the steam jacket against all comers; and that, in a word, we blow hot and cold. There is no real inconsistency, however. Our advocacy of the steam jacket is based on the received theory of the steam engine, and, until that theory has been demonstrated to be susceptible of modification, we shall continue to maintain that the steam jacket is right in principle and essential to economy. At the same time, however, it is our duty to call attention to the fact, that in certain cases, for reasons not clearly understood, practice is directly opposed to the theory of the steam engine, even though such a statement militates against our own views; and this leads directly to an explanation as to what our object is in writing as we have just done about the steam engine. It is our task just now to indicate the direction in which progress should be made during the coming year, and we earnestly desire to see some competent individual, or firm, or society, set on foot a series of experiments with a good steam engine of not less than 100-horse power indicated, which will determine in the first place, and if possible once for all, what is the true value of the steam jacket, a point about which no one is able or willing to supply a scrap of accurate detailed information derived from practice; in the second place, the true value of different measures of expansion and piston speeds; and, lastly, the value to be obtained from different systems of lagging cylinders and steam pipes, and the true amount of condensation which takes place within unclothed steam pipes and cylinders as a result of conduction to the bed-plate, etc., and radiation and conduction to the atmosphere. Such a series of experiments would cost a considerable sum, but they would be well worth the money. Let us suggest that the Institution of Mechanical Engineers in Birmingham take the matter up. We have no doubt that they could easily secure the co-operation of most of the leading firms of engine builders in the country, and thus the expense of the experiments being divided, it would not press heavily on any individual or firm.

Turning back to the past, the marine engine first claims a word. During the last year there has been an unparalleled demand for compound engines. Every house in the trade is overwhelmed with orders. But the fact in no way alters the opinions we have long since expressed. For low measures of expansion we hold the compound engine to be a mistake, and few even of the most enterprising modern builders venture to expand their steam beyond 6 or 7 times. The truth is that there is a fashion in steam engines as in everything else, and, compound engines being for the moment the rage, they are supplied at, we hope, remunerative prices. Already, however, we begin to hear complaints that the wear and tear, and complexity and trouble incurred at sea, more than counterbalance the advantage gained in economy of fuel. Of course the compound engine working with 60 lbs. steam expanded 5 or 6 times, is more economical than the now old fashioned type of engine working with 20 lbs. or 25 lbs. boiler pressure, and cutting off at $\frac{1}{4}$, or at most $\frac{3}{8}$ths stroke. But the economy of the new engine is not due to compounding, but to the high pressure and measure of expansion, and also to the improved type of boiler which, in addition to offering more surface for the power developed, is fed with distilled water, and as a consequence, always practically clean. The compound engine will run its course, and then settle down into its proper place, which is not at sea.

In locomotives nothing remarkable has been done during the year; our own

working drawings have kept our readers well posted up in the most recent practice. Mr. Stirling's great engine, with drivers 8 ft. 1 in. in diameter, and cylinders 18 in. by 28 in., cannot be said to have originated in 1871. We this week publish a working drawing and specification which supply the best possible information concerning recent practice in a totally different type of locomotive. We cannot resist the temptation to avail ourselves of the opportunity to thank the various locomotive superintendents of different lines, English, American, and Continental, for the courtesy with which they have placed their working drawings at our disposal. As regards American locomotives in particular, we shall at an early date supply some elaborate engravings of certain examples of the United States locomotive, illustrative of the most recent practice on one of the most important lines in that country. We have no small pleasure in stating that a type of engine first brought before the public in this journal, and persistently supported by us through evil report and good report, as being correct in principle and likely to supply a great want, has during the year taken the position it deserves. We allude to Mr. Fairlie's double bogie engine. Locomotives of this type are now being built, principally at the Avon Side Engine Works, for the Pesaqua, the Iquique, and the Mexican Railway to 4 ft. 8½ in. gauge; for a railway in Switzerland, with grades of 1 in 25, also 4 ft. 8½ in. gauge; for the Arica line, 2 ft. 6 in. gauge; for the Dunedin and Port Chalmers Railway, 3 ft. 6 in. gauge; for the Cape Breton Railway, 3 ft. gauge; for the Toronto, Gray, and Bruce line, 3 ft. 6 in. gauge; for a railway in Rio, 3 ft. 7½ in. gauge; while in America, Fairlie engines are being built by Porter, Bell, & Co., and by W. Mason for the Taunton and Maine line. In Russia the system has been fully adopted. Mr. Fairlie has had much up-hill work to overcome prejudice, and he fully deserves his success.

The use of steam on common roads has made great strides during the past year, and it is but fair to Mr. Thomson, of Edinburgh, to state that much of this progress is due to him. Let what will be said on the subject of india-rubber tires, it is day by day becoming more evident that an elastic wheel of some kind is essential to the full success of the traction engine or road locomotive. One of the great objections to its use hitherto urged against it has been the extremely slow speed at which alone it could travel. A nominal velocity of 4 miles an hour really means, when all deductions are made for the delays incurred by stopping for horses, taking in water, etc., a rate of not more than two miles an hour. This does not tell heavily in one sense against loaded engines, but it greatly increases the cost of working them, in that, in returning light for a second load, the duration of a trip is unnecessarily prolonged. A traction engine, to be really efficient, should be competent to travel, when it gets a chance, at 6 miles an hour; more is unnecessary for ordinary work. This speed cannot be obtained without springs of some sort. It is, however, very inconvenient to apply springs in the ordinary way to the driving wheels, for reasons too obvious to all builders of such machines, to require comment; and it must further be remembered that, even if this were not the case, the duties of a spring are but half performed when the spring is located between the engine and the axle. A 6 ft. wheel of sufficient breadth, to be strong enough, will weigh about 18 cwt., in some cases as much as 22 cwt. It is not too much to say that the dead weight, unaffected by the use of springs, will therefore amount in a 12-horse power traction engine to rather more than two tons, which is highly objectionable. The only way out of the difficulty lies in placing the spring at or in the tire of the wheel, and the success which has attended Mr. Thomson in his labors is due to the fact that his india-rubber tire exactly complies with this condition. The great objection to india-rubber lies in its enormous cost—over £100 for a moderate sized engine—and the uncertainty of the material. Thus the Ravee on her wonderful trip from Ipswich to Edinburgh and back, recorded in our pages, rendered one leading tire useless on her journey to the north, and she disabled another on her journey to the south. As these tires cost about £50 each, we have an outlay of about £100 for a journey of 900 miles, or a cost of 2½s. 2d. per mile for tires alone. The ruin of the tire in this

case was, no doubt, mainly due to the heating of the rubber caused by the high speed maintained.

In regard to electricity, we may here glance at one of the most neglected of its modern developments, which is now beginning to attract attention in certain quarters. The sisterhood of chemistry and electricity has been recognized ever since the latter became a science; but the close relationship of both to mechanical dynamics, although known in theory, has in practice received such scant recognition that very many scientific engineers might at first almost regard as an impertinence such questions as—"How many horse-power would be required to convert in 60 hours a ton of lead into one ton two cwt. 57 lbs. of plumbic peroxide?" or "How many foot-tons of work might it take to reduce electrically the metal in a ton of malachite?" Yet from the direction which electrical theory has taken, more especially during the past year, and from that which practical endeavors are now taking, it appears more than probable that the dictum which asserts that all physical science is one, will receive a verification in the future by the constant reference to engineering authority upon questions which would until now have been regarded as utterly beyond the province of the engineer. We know, in fact, that whilst the steam engine is a device for the conversion into mechanical work of the potential energy of chemical separation stored up in coal and other fuels by solar agency, the beautiful and comparatively recent magneto-electric machines of Wilde in England, and of Gramme and others on the Continent, are contrivances for the conversion of mechanical work into electrical energy. But the practical physicist is, moreover, now beginning to understand with what facility, and with what probable economy in certain cases, the electrical energy thus obtained may be converted into chemical work—how the steam engine can, by means which are dependent upon the correlation of all modes of energy, tear asunder and rearrange the atoms and molecules of compounds, so as to convert them into others, or to resolve them into elements of higher utility and value. Not very many years ago it was attempted to do this by means of the oxidation of zinc in a voltaic battery under economical disadvantages, which may be estimated from the fact that the indirect electrical work of 1 lb. of coal consumed in the furnace of a Cornish engine is, or should be, with a well constructed magneto-electric machine, about equal to that of 1 lb. of zinc consumed in a Daniell's battery, *i. e.*, to one million foot-pounds nearly. With this datum and Faraday's law of definite electro-chemical action, the engineer will require only to know, in terms of Daniell's cell, the electromotive force necessary to effect a given chemical reaction, in order to be able to calculate the expenditure of mechanical energy requisite to apply this reaction to a given weight of material; and he may thus determine what chemical operations may profitably be carried into effect by the combined agency of the steam engine and the magneto-electric machine.

THE MANUFACTURE OF LARGE MASSES OF IRON IN INDIA.

By GEORGE M. FRASER.

From "The Engineer."

Mr Mallet's article in "The Engineer" of the 15th ult.,* on the very singular iron column within the mosque of the Kutab, near Delhi, is one which cannot fail to be particularly interesting to all students of the history of iron metallurgy, and is certainly in great measure exhaustive and complete. Mr. Mallet, however, whilst coming to the conclusion that this monument is of malleable metal, seems yet inclined to suggest the possibility that at some distant date the iron workers of India may have had a knowledge of iron in its liquid form which at present they do not seem to possess, and of which knowledge history affords us no record. Mr. Mallet's great difficulty—and at first sight there can be no question that it is apparently an insurmountable one—is that—assuming

* See page 116 of the present volume.

the column to be of wrought iron—of forging such a mass of metal at a welding heat by the mere manual power within reach of Indian iron workers at the supposed date of its manufacture. The experience of many years spent in charge of an iron works in Southern India, where cast-iron was produced by the European method, but which experience also comprised constant intercourse with the native smiths of the country and a knowledge of the material they used, and of the method of its production and capabilities in manufacture, may perhaps entitle the present writer to offer what he ventures to believe will be considered by practical men a satisfactory explanation of how such material, labor, and capabilities might have been used to produce the column now under notice.

In the first place, then, the writer would record his decided opinion that the column of the Kutab is of wrought, or at all events of malleable iron; for during the whole course of his Indian experience, which included many visits to the native smelting furnaces in the Salem and Malabar Collectorates, together with the constant practice at his own works in the production of *edged*, not *chipping* tools, of the native steel, he never found anything approaching an attempt to *tap* one of these furnaces, nor heard any Indian workman speak of cast-iron but as of a material utterly useless to him, and beyond his ken.

The process of smelting, as pursued in Southern India, is probably sufficiently well known not to require any further description here, than, that in a perpendicular circular furnace about 6 ft. or 8 ft. in height, and of a diameter at its greatest width of about 18 in.—the blast to which is supplied by the alternate inflation and compression of 4 or 6 goat skins worked by hand, as in the ordinary smiths' fires of the country—the black magnetic oxide so common in the laterite formation is converted, not into cast iron, but rather into a mass somewhat similar to the loup of the Catalan forges, presenting in parts a crystalline and in others a fibrous fracture. The removal of these lumps—mootees they are called by the natives of Malabar—or loups, necessitates the breaking open of the whole of that part of the little furnace which corresponds to the timp and fore hearth of an English blast furnace; and in order to prepare for this, the charging at the top is stopped, as is also the blast, and the whole contents allowed gradually, as combustion exhausts itself, to sink down into the hearth, whence, when cool, it is removed. These loups or mootees (the writer must object to Mr. Mallet's term "pig," as applied either to these or any result of the cementation process, as the term certainly conveys, to English ears at least, the idea of cast iron) are generally from 80 lbs. to 112 lbs. in weight, and it is from the building up of lumps of metal, such as these, one upon the other, with such reheating and hammering as may have been found necessary to effect cohesion, that the writer conceives the Kutab column to have been produced. He cannot think that there is anything impossible in such a mode of proceeding, nor anything in the actual working of the material—which is of a most malleable nature, and weldable at a very low comparative heat—which the native smiths are unequal to performing. Fifteen inches diameter is certainly a very, very large bar; but it should be recollected that in the process just suggested it would only be the surface of each successive mootee (previously, of course, heated and hammered to the proper section) which would require to be at welding temperature for such surfaces might readily be produced in good charcoal fires without much injury to the iron so treated. The writer has himself seen shafting of between 6 in. and 8 in. diameter heated in open fires composed of charcoal and "bratties" (sun-dried cowdung), and welded to good joints by native smiths in the Madras Presidency. Conceiving, then, that the column may have been thus built up—and of course this supposition is directly opposite to the idea that it might have been composed of longitudinal bars welded together—we find the capital left to be accounted for; and the very form of this, is one which could readily have been produced by swaging, and finishing with such chipping (but this only to a small extent, the writer believes), as may have been found necessary. It is also to be recollected that the column itself has never, save, of course, in the act of raising it, been submitted to any severe strain, and that its cohesion has never in any way been tried in tension, as is ordinary shaft-

ing. Further, the extraordinary amount of quiet perseverance with which the natives of India are endowed, and the illimitable amount of mere manual labor which any great Eastern ruler could bring to bear upon such an object of ambition as the construction of a trophy or monument as this column may be considered, would all go to help us to the conclusion that this huge rod of iron may have been manufactured in such manner, and with such material and appliances as the writer has described.

Again, it may be remarked that, even supposing other similar columns to exist, as Mr. Mallet seems to think, yet even this very existence, in so confessedly small a number, proves them to have been quite exceptional productions, and not in any way portions of a systematic manufacture of large iron forgings. It is, too, a point well worthy of notice, that there would seem to be no examples left of what might be described as the intermediate stages of iron-working; *id est*, examples of forgings, which, whilst exceeding greatly in size and weight the present ordinary productions of the Indian iron smiths, would yet be of far smaller dimensions in every way than this column of the Kutab; for the large beams mentioned by Mr. Mallet can scarcely be classed in this category. The writer is, therefore, forced to the conclusion that this, and also the similar column spoken of, must be regarded as purely exceptional productions—types of no manufacture ever extensively or usefully existing in India, and indicating neither the possession of machinery calculated to produce such types in any number, nor even much smaller forgings. Exceptional, however, as they appear to be in every way, he yet ventures to believe he has pointed out the process by which, in all probability, they were manufactured; and if they can be regarded but as mere monuments of some now nameless ambition, they are yet wonderful examples of that ant-like perseverance and patient industry which in many ways mark the metal workers of India.

COMPASS COMPENSATION ON IRON SHIPS.

From "The Mechanics' Magazine."

M. Arson, engineer to the Paris Gas Company, has studied the variations in marine compasses, and designed an apparatus to compensate for the same in all latitudes, based upon the investigations of the mathematician, Poisson, and Mr. Airy, the Astronomer Royal.

Mr. Archibald Smith has already deduced from these theories practical rules, by the aid of which skilled mariners can compute, with a few observations, a numerical table of corrections to be applied to the observed compass-bearings; and Admiral Napier introduced the representation of the series of observations by a curve interpreting the indications of the needle.

But these methods are scarcely within the reach of ordinary navigators, on account of the delicacy of the observations required for the table or the curve; and, moreover, the resulting corrections are only applicable for the latitude of the original observations, and to the needle with which they were made, and therefore fail in general accuracy and application.

M. Arson, however, has sought, by special appliances, separate compensations for permanent and induced magnetic action, so that the compass shall act as if solely influenced by terrestrial magnetism.

It is well known that all the separate pieces of iron that enter into the construction of the ship, the machinery, fittings, cargo, and armament, having undergone certain mechanical treatment, possess certain permanent magnetism, independent of position, of invariable intensity; and, in addition, they are endued, by the inductive action of the terrestrial globe, with a transitory magnetism, varying according to their position on the earth's surface.

To compensate for the effects of permanent magnetism, M. Arson applies three bundles of magnetized steel wire, two of which are fixed horizonally under the compass, one in the longitudinal axis of the ship, the other transversely to it at right angles. The power of these magnets depends upon the number of wires,

and may also be varied within certain limits by raising or lowering them, for which purpose they have a slight motion in vertical grooves.

Two stations in the same quadrant suffice to regulate this compensation, since while operating on one of the magnets at right angles to the needle, the other magnet, being parallel to the needle, has no effect.

The third magnet of wires is movable; for, inasmuch as the effect of the ship's permanent magnetism on the compass-needle varies with change of position, no arrangement of fixed magnets alone can compensate for it. Therefore, the two fixed magnets effect only a part of the whole compensation required; and if a curve is drawn representing the variations of the compass-needle due to the permanent magnetism of the ship in successive positions, and also, from the same co-ordinate axes, a curve of inverse deviations or compensations due to the fixed magnets, the differences between the ordinates of these curves supply the measure of the supplementary compensation required.

This, then, is the function of the movable magnet, which has a position appropriate to every change. It is attached perpendicularly to a horizontal axis at a point dividing its length unequally. This horizontal axis is originally placed in the true direction of the disturbing pole of the ship, determined by ascertaining the point in the revolution at which the needle is unaffected. By causing this axis to revolve, the magnet also revolves in a vertical perpendicular plane, and thus its poles may exercise a variable action upon the poles of the needle.

But, by a tentative process, M. Arson arrived at an arrangement that by the turning of the axis through an angle, the double of that of the evolution, the resultant of these actions for each change of position becomes equal to the deviation that remains to compensate for the difference between the curve-ordinates referred to. A bevel-wheel fixed upon the horizontal axis is actuated by a horizontal bevelled pinion of $\frac{1}{2}$ its diameter, the vertical shaft of which carries a horizontal repeating circle against a fixed index corresponding in fact to the circle of the compass itself.

Thus, when following a course making a given angle with the magnetic North, all that is necessary is, to turn the horizontal circle until the index marks the angle of the proposed route, whereby the vertical magnet will have revolved through twice the angle, and will be so situated as to complete the supplementary compensation required to neutralize the effect of the permanent magnetism of the ship on that course.

In compensating for the induced magnetism of the iron hull, the engines and boilers, and the iron of the armament and cargo, M. Arson places on each side of the compass a bundle of soft iron wire, suitably proportioned. In sailing vessels, where the influence of hull predominates, the deviation is always negative in the N. E. quarter, and the 2 parallel bars are moulded on a support caused by horizontal gearing to revolve through an angle equal to the angle described by the horizontal axis of the apparatus; in a steam vessel, where it is the magnetism of the bodies carried that predominates, the deviation is positive, and the 2 bars are fixed upon the support of the apparatus. When these 2 bars have been regulated so as effectually to compensate for the magnetism of induction in any one position of the ship, they will compensate for it in all positions, and in all latitudes, because their magnetic condition undergoes changes in the same sense and degree as that of the pieces of iron in the ship, and consequently the equilibrium, once obtained, is permanent.

This invention has been applied on board the steam vessel Europe, of the Transatlantic General Steam Navigation Company, and it is most important and desirable that its efficacy should be thoroughly and completely demonstrated by practical tests and experience. If confirmed, the independence of the magnetic needle on board of iron ships will be restored to it, to the manifest advantage and security of all mariners and shipowners.

LEVANT TELEGRAPHS.—The Telegraph Maintenance and Construction Company has completed the laying of the cables uniting the islands of Candia, Cyprus, Rhodes, Chio, Samos, and Mitylene to the mainland of Asia Minor.

MANUFACTURE OF GUNPOWDER DURING THE SIEGE OF PARIS.

From "The Engineer."

Towards the end of the summer of 1870 it became evident to the most enthusiastic partisans of the French cause that the almost unparalleled reverses which had attended it would culminate in the siege of the capital by the victorious enemy. Under these circumstances, prompt and urgent measures were at once necessary in order to insure to the anticipated besiegers an adequate supply of the material of war. Obviously gunpowder occupied a prominent place in the deliberations of the defenders of Paris, and it was at once determined to bring within the walls of the city as large a quantity of that indispensable article as could be collected on short notice. There existed several powder manufactories and magazines in the neighborhood of the capital which would inevitably fall into the hands of the enemy on his advance upon the city. These, it was resolved, should be evacuated, and their contents transferred where they could be rendered available during the impending siege. By these means the supply in the manufactory of Bouchet, a military establishment devoted to the production solely of cartridges and powder for war purposes, was removed out of the reach of the foe. Similar foresight insured the safe removal to Paris and Lyons of the contents of the magazines of Saint-Ponce and Vonges, which included a considerable quantity of mining and sporting powder. When these removals had been successfully accomplished there was upwards of 2,000 tons of powder available for the use of artillery, about 45 tons for the purposes of mining and military engineering, besides a certain quantity of sporting powder which was regarded in the light of a reserve, and only to be employed when matters came to the worst. It was calculated that, owing to these precautions, the citizens of Paris had powder sufficient to enable them to stand a siege of 3 months; but when the capital was actually invested, and the forts maintained an almost incessant cannonading, serious doubts began to be entertained whether a consumption so excessive would not speedily exhaust the supply, abundant though it was. Again, the duration of the siege was extremely uncertain, and might be prolonged to a period that would render it indispensable to procure a fresh stock of ammunition at all risks. In the face of this contingency the wisest plan was clearly to set to work to utilize such materials as might be available for the manufacture of gunpowder. There could be no harm in having an excess of that article, but a deficiency would be attended with the most disastrous results. There was plenty of saltpetre in Paris—one of the essential ingredients—capable of being utilized at once. Moreover, since the commencement of the siege, several workshops had been established for the manufacture of cartridges, which afforded a considerable amount of employment to men and women, who, without such employment, would have become objects of public charity. A real advantage thus resulted from the maintenance of those workshops, which would cease directly the store of powder which was used in the preparation of the cartridges became exhausted, unless means were provided for insuring a fresh supply. It is true that gunpowder manufactured in what might be fairly termed an improvised establishment, and under very exceptional circumstances, could not be expected to be of so good a quality as the same article produced under the normal state of affairs. Nevertheless, there was no choice in the matter, so it was ultimately decided to commence the undertaking in premises situated on the Boulevard de Phillippe-Auguste, in the neighborhood of the Barrière du Trône.

Before proceeding to describe further the method of manufacture carried on in this particular instance, it will be interesting to review some of the methods that have been adopted, when the ordinary one has, for some cause or another, been unavailable. Numerous explosive substances are known to chemists and pyrotechnists, the action of which is very analogous to that of gunpowder, and the effect of which is in many instances considerably more violent. The majority of these substances are of recent date. Gunpowder made with chlorate instead of nitrate of potash, is an exception, and it is

with this that we shall commence. It is much stronger than ordinary powder, but, owing to its great disruptive power, is unsuitable for the use of artillery or small arms. But this feature does not constitute a defect when it is otherwise employed, and thus we find that the department of military engineers, on discovering that their supply of mining powder was becoming rapidly exhausted, and being unwilling to draw upon the store reserved for the artillery, accepted a contract in the month of October, 1870, for a supply of chlorate powder wherewith to charge their torpedoes. This material answers admirably for this purpose, and would no doubt have been used in large quantities, had not a terrible accident occurred at the very commencement of its manufacture, which effectually put a stop to any further prosecution of it. About mid-day on the 6th of the above mentioned month a tremendous explosion threw into consternation the whole of the quarter of Grenelle, and completely shattered to pieces the premises of M. Deplazanet, a manufacturer of chemical products, situated in the Rue de Javel. Thirteen dead bodies and six wounded testified to the violence of the explosion. The cause was attributed, after a careful examination into the facts of the case, to a serious imprudence committed in the drying of the material. The powder which M. Deplazanet contracted to supply was composed of 2 parts of chlorate of potash, 1 part of prussiate of potash, and 1 part of powdered sugar, a mixture which had been long known as one which involves great danger in its preparation. What renders the occurrence the more to be deplored is that there was no absolute necessity for employing these ingredients, which were comparatively of a high price. The same end, so far as the effect of the powder was concerned, could have been attained by the use of other components. The proportion of chlorate of potash might have been reduced, and the sugar replaced by charcoal, without in the least impairing the practical value of the powder for mines and torpedoes. It is, however, of no consequence to discuss the matter, as the one explosion put an end to any further manufacture of the compound containing chlorate of potash. The next attempt was made shortly afterwards at Grenelle, and in this instance gun-cotton was the subject of trial. This substance is capable of being used in firearms, but not unconditionally. In order to make it available during the siege of Paris certain modifications and alterations must have been made in both the cannons and rifles, which were impracticable under the circumstances. The explosive was not intended to charge either cartridges on a small or large scale. The object was to fill shells with it, so as to economize as much as possible the ordinary powder; and there is no doubt, from the experiments undertaken, that hollow projectiles charged with it were exceedingly destructive in their effect. Although this attempt was of a far more promising character than its predecessor, it met with no better result. On the 27th of the same month that witnessed the former catastrophe a second explosion occurred, which destroyed the workshops at Grenelle, where the cotton was prepared. The cause of this accident was accurately traced, and found not to originate from any mismanagement or error in the preparation of the compound. A workman had gone upon the roof to solder some parts of it, and in some manner or other set it on fire. The damage in a pecuniary point of view was not great, but four persons were badly burnt. For the rest, the *coup de grace* was given to the manufacture of gun-cotton for the future.

The two substances that have been considered, that is, gun-cotton and gunpowder containing chlorate of potash, do not occupy the first rank in the scale of explosive compounds. This distinction belongs to others, such as nitro-glycerine, dynamite, picrate, and the cartridges of compressed cotton invented by Mr. Abel.* These cartridges are very little known in France, but during the year 1870 several experiments were conducted by the engineers of "Les Pons et Chaussées," which directs attention towards them. When used for blowing up walls and other obstacles they proved eminently successful. Their manufacture presents no more difficulty than that of the ordinary gun-cotton. The cartridges are formed of cotton prepared as usual and strongly compressed, and fired by means of a fulminating cap, which is exploded by either the electic spark or a safety fuze. As

* To these should be now added "Krebb's explosive," better known under its more familiar title of "lithofracteur."

considerable advantage would have resulted from possessing a supply of these cartridges, their manufacture was proposed to the Minister of War during the first week of the siege by a committee of engineers. The idea was at first adopted, but for various reasons was subsequently abandoned, and the whole proposition fell through. Passing on to the subject of picrates, their nature and properties have never been a question of any doubt. Many attempts have been made to utilize them for fire-arms, but their disruptive tendency has defeated all endeavors to so apply them. Their actual destructive effect is probably less than that of other explosives, although it is difficult to determine this in an accurate and conclusive manner. The only superiority they appear to possess is that of greater stability, but this is more than counterbalanced by the difficult character of their preparation. As an explosive compound of any value for warlike purposes, nitro-glycerine may be altogether omitted, since its preservation and transport are attended with dangers that few would be willing to incur. It might possibly be used were it manufactured on the spot.

The same disadvantages do not attend the somewhat similar compound dynamite, which may be regarded in some degree as nitro-glycerine solidified by its admixture with a porous description of sand, while at the same time it possesses an equal amount of explosive power. Although dynamite cannot be used in fire-arms, yet it might certainly serve for filling hollow projectiles. In order to ascertain this, experiments were conducted at Mont Valérian in presence of the Minister of Public Works, which succeeded in establishing the fact that shells filled with dynamite could be exploded with all the facility desired, but that there the merit of the explosive ended. It is well known that besides the mere explosion there are other conditions to be fulfilled before the proper effect of a shell is produced.

There are two principal conditions attached to the bursting of a shell, the fulfilment of which can alone insure its success in a destructive point of view; one is, that the shell should be shattered into as many fragments as possible, and the other that those fragments should be scattered in every direction to as great a distance as the charge will allow. The former of these conditions is fulfilled by the enormous tension of the gases which are developed at the moment of explosion, and the latter by the progressive action of the same gases. When this action is almost instantaneous, as happens in all explosives whose disruptive power is very great, the dynamical effect is little or none. The explosion itself may be terrific at the spot where it actually occurs, but there it ends. It does not travel to any distance. There is no question but that by the aid of dynamite, blocks of granite and metals can be shivered to pieces, upon which ordinary powder would produce no effect whatever; but on the other hand, where substances which offer less solid resistance are to be operated on, a powder possessing an inferior degree of power is to be preferred. It is an error to imagine that it is always advantageous to employ in mines the most violent explosives. The explosive force of the compound should be proportional to the resistance to be overcome. It is thus readily perceived that dynamite would not answer so well as ordinary gunpowder in the case of mines intended to be sprung in such a manner as would destroy an enemy's works and overwhelm him with the *debris*. The one particular in which the incontestable superiority of this compound is apparent is that in which walls, gabions, entrenchments, and other obstacles are to be removed. In this respect it is unrivalled. A good deal has been stated respecting the value of dynamite as an agent for placing cannon *hors de service*, but opinions differ on this point. It must be borne in mind that the object aimed at is not so much the permanent destruction of the guns of an enemy as the rendering of them temporarily useless. Artillery which loads by the muzzle is "spiked" with a rapidity which cannot be surpassed, and those which are breech-loaders are equally readily rendered incapable of being fired by the breakage or abstraction of any of the movable parts of the breech. In any case it is far preferable to let a soldier carry a hammer with him into action than to encumber him with explosive materials, which are of no use to him as ammunition. From the "Transactions of l'Academie des Sciences," in which the results of some of the trials made with dynamite are recorded, it does not appear that very much has been done with it. With the

exception of the attack on Buzenval, where it was employed to blow up the walls of a park, it has scarcely passed the experimental stage, and cannot be said to have reached the practical. The definite point arrived at is that a given effect can be produced with a comparatively small quantity of the material. It would, however, be forming a very unfair opinion of this powerful explosive were we to judge of its properties solely from the evidence afforded by the examples manufactured in Paris during the siege. The descriptions of dynamite prepared by the Prussians are very superior in quality. The French kinds contained a small proportion of nitro-glycerine, and the porous medium which was used, probably for want of something better, was not so well adapted for absorbing the explosive oil as the Kieselguhr, or silicious ingredient of M. Nobel. From the above remarks it is evident that the part played during the siege of Paris by what might be termed, in comparison with ordinary gunpowder, extraordinary explosives, was of little or no practical value, and consisted simply in blowing up some 20 persons engaged in their production, together with the premises in which they were manufactured.

We may now return to the powder manufactory of Philippe-Auguste, which, it had been decided, should be vigorously set to work directly the precise method of manufacture to be adopted had been determined upon. At present there are numerous processes existing for making gunpowder, and under ordinary circumstances each particular kind, whether cannon, mining, or sporting powder, is prepared by distinct varieties of machinery. Of late years it has been the custom to vary the manufacture of powder intended for war purposes accordingly as it is intended for ordnance or for small arms. In France the question has been raised whether powder intended for the heavy marine guns should not be prepared independently of the kind used for artillery, so that there would thus be three distinct kinds of gunpowder employed in warfare. Considering the conditions under which the establishment of Philippe-Auguste was erected, it is not to be expected that it could enlist in its service the aid of costly and elaborate machinery. It was, therefore, at once felt that the method of manufacture must be a simple process, easily manipulated, rapidly got into productive order, and answering all the actual requirements of the emergency. For these reasons the old method, as well as that of mills by which the powder for the Chassepot rifles and mitrailleuses was prepared, were excluded. The system of round barrels, used specially in the preparation of mining powder, might have been modified to suit, as its advantages were evident, so far as rapidity and economy were concerned. But it presented some difficulties with respect to the production of powder of a fine grain, which is indispensable to small arms. This objection was fatal to it, as the most urgent demand was for powder for the Chassepot rifles. For the same reason, powder prepared by agglomeration was rejected. Finally, M. Mauronard, who was appointed by the Minister of War the chief of the new establishment, adopted the method of "Formes et Presses." This was not a novel process, as it had been employed during the first revolution, when matters were pretty much in the same state. It then earned the name of the "revolutionary process," or the "Grenelle process," since it was at that place the first manufactory was erected. A violent explosion shortly afterwards destroyed not merely the whole of the manufacturing premises, but a large portion of the neighboring quarter as well. This part of Paris seems to have been a general victim to this kind of accidents. A full description of the method will be found in "L'Art de Fabriquer la Poudre-à-Canon," by MM. Botée et Riffault, and also in the "Guide Pratique de la Fabrication des Poudres," of Major Sterk. By utilizing some recent discoveries the old Grenelle process was rendered available for the production of powder during the recent siege of the French capital. The first step in the operation is to triturate separately the several ingredients, and to reduce them to the most complete state of subdivision, which was accomplished by the "Broyeurs cars." This was the first time the machine had been employed for powder, and unfortunately the only ones that could be obtained were originally adapted for the grinding of bones, or other substances infinitely more refractory than the components of gunpowder. Although the result cannot be stated to have been perfectly satisfactory, yet it was sufficiently so to

warrant the expectation that the success would be perfect, when proper grinders or crushers were procured, adapted for the trituration of saltpetre, sulphur, and charcoal. The second phase of the process consists in the intimate mixture of the ingredients, after their thorough trituration, so as to render them completely incorporated. Instead of bringing at once the three ingredients into contact, the plan adopted in the preparation of mining powder was followed, namely, that of binary and ternary trituration, which allows of a more effectual admixture, with a corresponding diminution of danger. The compression of the substance, or the formation of the cake, which presents no features demanding especial notice, is the third part of the process.

There have been some improvements introduced recently into the manufacture of gunpowder which considerably simplify the loading and unloading of the presses. Instead of enclosing the powder in frames, it is placed in successive layers upon the plate of the press, each layer being separated as usual by a sheet of copper and a rag slightly wetted. The frames are thus abolished altogether. The proportion of water that should be mixed with the ingredients of powder is a very important element in its preparation. In the powder made at Paris during the siege this proportion was extremely small, and did not exceed above 4 per cent. This was not, however, a matter of choice, but of necessity. As there were no drying rooms nor apparatus, it was essential that as little water should be used as possible. The ingredients were nearly dry; the small quantity of moisture present, which was just sufficient for the formation of the cake, was driven out at the finish of the process. After leaving the presses the cake was first broken up by mallets, and the fragments transferred to the "Grenoirs-à-cylindre," above which were fixed sieves or strainers to separate the large grains from the powder. This cylindrical apparatus has been rarely used in France, and is no longer so now. The example put up on the premises at Phillippe-Auguste was taken from the English workshops, and gave very good results. The whole process terminates with the polishing of the powder, which operation not only polishes, but dries the grains as well. It is performed, as is well known, by placing the powder in a closed cask or barrel, and turning it about for a certain period, by which motion the grains acquire solidity and the consequent formation of dust is prevented. Some years ago a M. Laville, having remarked that in the course of the operation of polishing, the cask became appreciably heated, proposed to utilize the heat thus developed in drying the grains. For this purpose it is only necessary to employ a cask closed at one end and opened at the other, in such a manner as will allow the moisture to escape. This plan answers very well when there is but a small quantity of water mingled with the powder, as occurs in the case of sporting powder. It would be impossible to thoroughly dry powder by this operation, but even if it could be accomplished it is not needed. The powders that are the best dried invariably absorb about one per cent. of water on coming into contact with the atmosphere, so that there would be no advantage derived in pushing the process to a complete desiccation. The powder made in Paris at the time we write of was dried in the polishing casks, and it now remains to mention the tests applied, in order to arrive at a correct estimate of the value of it when applied to the purposes of warfare. Gunpowder made with saltpetre is not endowed with the great disruptive force of that into the composition of which chlorate of potash enters, and therefore the two principal qualities to which attention must be directed are cleanliness and durability. In other words, it must not foul the gun, and it must be easily kept in a state of good preservation and efficiency. The latter consideration may be neglected in instances similar to the one under notice, where but a short period intervened between the manufacture of the article and its subsequent consumption. Cleanliness, or the property of non-fouling, is an indispensable one in all powders intended to be used in small arms. In fact, the old description of gunpowder could not be employed in the breech-loading rifles of the present day. The new powder was tried by firing 100 consecutive rounds with the same Chassepot, and was found to behave equally well as the ordinary mill powders. The strength was tested by means of the ballistic pendulum, upon which a Chassepot was mounted. The initial velocity of the ball, with a

charge of 89.5 grains of powder, was 1,250 ft. per sec., while that produced with the ordinary powder under similar conditions was 1,390 ft. per sec. The difference was not sufficient to indicate any great inferiority in the new preparation, or to render it unsuitable for using in rifles and artillery. Moreover, as the density of the Phillippe-Auguste powder was greater than what there was any necessity for, the initial velocity of the ball could be increased by diminishing it and making the grain finer. On the whole, the attempt was decidedly successful—so much so that the question will be asked, why this mode of manufacture could not be universally employed, since it is much simpler and more rapid than the methods usually adopted for the preparation of the same material. In order to give a satisfactory reply to this question, the behavior of the powder with other weapons than the Chassepot must be taken into account, such as rifles loading at the muzzle, and also smooth-bore guns. The difference at once becomes manifest. The initial velocity of the ball decreases in the muzzle-loading rifle, and becomes very much reduced in the smooth-bore. The explanation of these facts is simple. The initial velocity of the ball depends, according to the nature of the weapon with which it is fired, upon the absolute strength of the powder, and its "vivacity." The first of these will to a great extent suffice for rifles similar to the Chassepot, in which the ball is completely forced into the grooves of the bores, in consequence of the loading taking place at the breech. But in rifles which load at the muzzle the ball is only partially compressed in this manner, and the vivacity of the charge comes into play. This attains its maximum in the smooth-bore gun when there is no compression whatever, and consequently a good deal of windage. Thus the powder prepared by casks and presses, although suitable for needle-guns, would only answer indifferently well for arms of another description, especially fowling-pieces. Gunpowder manufactured by the usual processes have in these instances an incontestable superiority. Apart from all other considerations, the great merit of the undertaking commenced in the premises of Phillippe-Auguste was undoubtedly the power of manufacturing in so short a period any gunpowder which should have been of real service to the besiegers. The daily production at first amounted to between 2 and 3 tons, and afterwards reached between 5 and 6. Had circumstances required it, a greater quantity could have been provided. We trust that the necessity for establishing a powder manufactory in the heart of Paris may never again occur.

DEPHOSPHORIZING IRON ORE.

From "Engineering."

Metallurgists have for a long time past made great efforts to utilize iron ores which are contaminated by phosphorus, and which in consequence yield an iron of inferior quality, it being almost invariably cold-short. The quantity of iron ore so contaminated is enormous in many of the more recent geological formations, such as the oolitic, cretaceous, and tertiary formations, where the ore is either found in the shape of a carbonate or a hydrate of iron, always intimately contaminated by phosphate of lime. Of this character are the heavy beds of iron ore in the Middlesbrough district, in Luxembourg, Lothringen, Bavaria, Hanover, Bohemia, and many other localities. It was the phosphorus which forbade the use of a number of these ores for many years, until modern metallurgists had learnt, by using larger furnaces and more limestone, and by adopting a judicious admixture of other ores, to extract a cheap and tolerable iron from them. Nevertheless, it has always been a desideratum to neutralize the injurious influence of the phosphorus in one way or the other. Some engineers have endeavored to extract the phosphorus from the ore, wherein it is contained in the shape of basic phosphate of lime, which is insoluble in water, and the object of all their exertions being to render this compound soluble by converting it into acid phosphate of lime by the action of other mineral acids, which would combine with a part of the lime, and set an equiva-

lent of phosphoric acid free to combine with the rest of the phosphate of lime, thus forming a superphosphate. This idea is stated to have been lately successfully carried out by T. Jacobi, of Adalberthütte at Kladno, near Prague, by exposing the ore to a solution of sulphureous acid in water, or to the simultaneous action of sulphureous vapors and cold water, when this acid forms a soluble compound with the lime, and at the same time converts the rest of the phosphate to the soluble form, so that it can be washed away with cold water. The inventor exhibited his process during the last meeting of the Association of German Engineers and Architects, at Prague, on November 3d, 1871. The samples of fibrous and fine-grain bar iron and puddled steel made from such dephosphorized ore, and produced to the Association, were of an excellent character, and found unanimous approval. The sulphureous gas is either produced by burning sulphur or by the calcination of pyrites or other minerals containing sulphur. The same end has been attained by another engineer, B. Osann, of Potsdam, by employing in a similar way diluted hydrochloric acid, which is obtained very cheaply in quite a novel mode. At the above mentioned rock salt mines of Stassfurt and Leopoldshall, large masses of chloride of magnesium are obtained, together with the salts of potassium, and are thrown away as valueless. Now, if this chloride of magnesium, which contains always a considerable amount of water, be heated to about 110 deg. Cent. or 230 deg. Fahr., it gives up so much water as to form a trihydrated salt of chloride of magnesium, and if this is rapidly heated to the melting point of lead it is decomposed, giving up vapors of hydrochloric acid, when hydrate of magnesia is left as residue in the retort. The hydrochloric vapor acts exactly as was described of the sulphureous acid. Both of the processes above described are worthy of attention ; but the information we have received concerning them is not as yet sufficiently detailed to enable us to form any decided opinion regarding their practical merits.

Other metallurgists have sought to get rid of the phosphorus during the puddling of the iron, or even just before, when the pig iron runs from the taphole in the moulds. For removing the phosphorus during the operation of puddling, Director Spamer, at Ilsederhütte, in Hanover, adds to each heat of 500 lbs. of pig iron about 6 lbs. of fluoride of calcium (fluorspar), which readily melts when brought in contact with the iron, so that it can be intimately mixed with it, when the fluorine combines with the silicon of the iron to fluor silicon, and phosphoric acid is absorbed by the lime and carried into the tap cinder, or finely powdered fluorspar is thrown into the iron-moulds before they are filled with liquid iron when tapping the blast furnace. In both instances the result obtained is said to be excellent, the cold-shortedness of the bar iron having entirely disappeared. This appears to be a modification of the Henderson process, which has lately attracted much attention in America.

ON JOURNAL FRICTION IN STEAM ENGINES.

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S.

From "The Engineer."

(1) OBJECT OF THIS COMMUNICATION.—The object of this communication is not to publish any new research or original theory, but to set forth and illustrate in a simple manner some elementary principles relating to a subject in which, though it has long been familiar to engineers, their practice sometimes differs widely—that of the construction of steam engines, and especially of marine steam engines, so as to diminish the work wasted in overcoming the friction of the shaft journals. It is well known that in engines with more than 1 cylinder the efforts exerted through the piston-rods on the cranks, and thence transmitted to the bearings of the shaft, may be made to a greater or less extent to balance each other, thus diminishing friction and promoting economy of power; and that the balance of efforts, and consequent economy of power and of fuel, may be in many cases improved by increasing the number of cylinders. Against this advantage have to be set the additional

complexity, and consequent additional cost, of an engine with an increased number of cylinders. It is obvious that no rule of universal application can be laid down as to whether the preference is to be given to fewer cylinders and greater journal friction, or to more cylinders and less journal friction; but that each case must be decided according to its own special circumstances to the best of the judgment of the engineer. The application of that judgment may be facilitated by showing the results to be expected in a set of examples, such as those contained in the sequel of the present paper.

(2) Friction at Crank Journals.—The proportion which the work lost in overcoming friction at a single crank journal bears to the whole work done in driving the crank, is the product of the following factors:—First, the ratio in which the mean pressure at the bearing surface of the journal exceeds the mean effort exerted by the piston on the crank. This ratio is very nearly equal to the mean value of the secant of the angle of obliquity of the connecting rod to the piston-rod, and is unity plus a small fraction, unless the obliquity is great. Secondly, the ratio in which the friction is less than the bearing pressure; in other words, the coefficient of friction. This may be taken as ranging from .04 to .08, according to the smoothness and state of lubrication of the bearing surfaces. Thirdly, the ratio in which the distance through which the friction has to be overoome at each revolution is less than the distance through which the effort is exerted; in other words, the ratio in which the circumference of the journal is less than twice the stroke of the piston. So long as the 3 factors are the same the product is the same: that is, the fraction of the whole work of the engine which is wasted in overcoming the friction of crank journals is the same, whether the work is done in 1 cylinder or in several, provided the coefficient of friction, the mean obliquity of the connecting rods, and the proportion borne by the diameter of a crank journal to the stroke are unaltered. In the examples chosen for illustration it will be assumed that those quantities are unaltered: that assumption simplifies the calculations, and does not affect to any important extent the accuracy of the conclusions arrived at. The loss of work through friction at crank journals may be taken as not sensibly affected in practice by the greater or less number of cylinders of which the engine is made up.

(3) Friction of Shaft Journals.—The part of the work wasted in overcoming friction, which is capable of diminution by means of a suitable distribution of power amongst two or more cylinders, is that which is expended at the bearings of the shaft journals. The principles according to which such diminution may be effected depend upon the difference between the resultant of a set of forces and what may be called their aggregate. The aggregate of a set of forces is the sum of their magnitudes, in the arithmetical sense of the word sum; that is, the quantity obtained by adding these magnitudes together, regarding them all as positive. The aggregate of a set of forces is only equal to their resultant, when all the forces act in the same direction. In every other case the aggregate is greater than the resultant. For example, when a pair of equal and opposite forces either balance each other, or form a couple, their resultant force is nothing; their aggregate has twice the magnitude of each of them. When two forces act through one point in different directions their resultant is represented by the diagonal of a parallelogram; their aggregate, by the sum of the two sides, which is always greater than the diagonal. Hence it is obvious that two sets of forces may have equal resultants, but very different aggregates. Supposing, as is always the case in marine engines, that the pressure or reaction due to the resistance overcome is borne by special bearings for that purpose (such as paddle shaft journals, and propeller shaft journals), it follows from the principles of dynamics that the mean value of the resultant of the pressures at the engine shaft journals is equal and opposite to the mean value of the resultant of the pressures at the crank journals, combined with the weight of the shaft; but the aggregates of those two sets of pressures may differ in any proportion. When several pressures act at once upon one bearing, the total friction is that due to their resultant, and is the same as if the several pressures were replaced by one pressure equal to their resultant. But when several pressures are applied, each to a different bearing, the total friction is that due to their

aggregate, which cannot be less than their resultant, and may be greater.

(4) Comparison of Crank Journal Friction and Shaft Journal Friction.—Assuming the coefficient of friction to be the same (as it really is with smooth surfaces and good lubrication) for the crank journals and for the engine shaft journals, the ratio which the work wasted at the shaft journal bears to the work wasted at the crank journals is the product of the following factors. First, the ratio which the diameter of the shaft journals bears to the diameter of the crank journals; a ratio which seldom differs much from that of equality. Secondly, the mean value of the ratio which the aggregate of the pressures at the engine shaft journals bears to the aggregate of the pressures at the crank journals. The economy of power, so far as it arises from the diminution of friction at the shaft journals, mainly depends upon so designing the engine as to make this second factor as small as possible; and for practical purposes, indeed, we may regard its smallness as a measure of the comparative economy of frictional work in different engines, so far as that work is done against journal friction.

(5) Principles of the Determination of Comparative Economy in Journal Friction.—The process of determining the ratio already referred to, which the mean value of the aggregate of pressures at the shaft journals bears to the aggregate of pressures at the crank journals, involves two steps. First, the finding of the mean value of the ratio that the resultant force of the pressures at the crank journals bears to the aggregate of those pressures, and also the arm of the resultant moment of those pressures relatively to an axis transverse to the axis of rotation; that resultant force and resultant moment being, in other words, the tendencies of the pressures at the crank journals to shift the shaft parallel to itself, and to alter its direction respectively; and, secondly, the finding of the pressures at the shaft journals in terms of that resultant force and resultant moment, and of the weight of the shaft.

These processes are to be performed for the various parts of a revolution in which they give different results; and from those results a mean value of the required ratio is to be deduced.

During the second process the effect of the weight of the shaft may in many cases be neglected, provided the pressures due to its action alone are less than those due to the vertical component of the resultant of the pressures at the crank journals; for then the weight diminishes the pressures at the shaft journals as much during one-half of each revolution as it increases them during the other half, or nearly so; so that its influence on the mean value of the pressures at the shaft journals vanishes or becomes insensible. The weight of the shaft may be neglected also, in every case in which it is very small, compared with the resultant of the pressures at the crank journals. On the other hand, when the pressures at the crank journals are so adjusted as to make the pressures at the shaft journals due to their actions, either nearly vertical, and less than those due to the weight of the shaft alone, or very much less than those latter pressures, and in any direction, the mean aggregate pressure at the shaft journals is very nearly equal to the weight of the shaft simply; and this realizes the highest practicable economy in the journal friction of steam-engines.

(6) Formulæ.—To find the aggregate of the pressures on the crank journals, the thrusts or pulls along the connecting rods are simply to be added together. To find the resultant of those pressures and its moments, let P be one of them, i the angle which it makes with a line pointing vertically downwards, Y its horizontal component, Z its vertical component, positive downwards. Then $Y = P \sin. i$, and $Z = P \cos. i$, observing that cosines of obtuse angles are negative. The horizontal and vertical components of the required resultant are respectively ΣY and ΣZ (Σ denoting algebraical summation, in which positive and negative quantities are distinguished). Let R denote the resultant, then

$$R = \sqrt{\{(\Sigma Y)^2 + (\Sigma Z)^2}$$

For a rough approximation, such as is in general sufficient in treating the questions to which this paper relates, the obliquity of each connecting rod to its piston-rod may be neglected, so that instead of putting for the angle i the varying angle made by the connecting rod with the vertical, we may put the constant angle made by the piston-rod with the vertical,

or, in oscillating engines, the mean value of that angle. To find the resultant moments, let the axis of rotation be that of x: assume a convenient point in that axis for the origin of co-ordinates—in general, a point midway between the centres of the two shaft bearings is the most convenient. Conceive two transverse axes perpendicular to the axis of x, to traverse the origin; the axis of y horizontally, and the axis of z vertically. Let x denote the distance of one of the forces P from the plane of y and z the moment of that force about the axis of y is x Z, and about the axis of z, x Y; the resultant moments of the pressures about those axes are respectively $\Sigma\, x$ Z and $\Sigma\, x$ Y. To find the pressures at the shaft bearings due to the pressures at the crank bearings, irrespectively of the weight of the shaft, let the origin be supposed to be midway between the bearings, and let $2\,b$ be their distance from centre to centre. Let V and V^1 be the vertical pressures, and H and H^1 the horizontal pressures at the two bearings respectively. Then for the bearing at the positive side of the origin we have

$$V = \tfrac{1}{2}\Sigma Z + \frac{\Sigma\, x\, Z}{2\,b};$$

$$H = \tfrac{1}{2}\Sigma Y + \frac{\Sigma\, x\, Y}{2\,b};$$

and for the bearings at the negative side of the origin

$$V^1 = \tfrac{1}{2}\Sigma Z - \frac{\Sigma\, x\, Z}{2\,b};$$

$$H^1 = \tfrac{1}{2}\Sigma Z - \frac{\Sigma\, x\, Y}{2\,b}.$$

The resultant pressures are respectively

$$\sqrt{(V^2 + H^2)} \text{ and } \sqrt{V^{1\,2} + H^{1\,2}});$$

and their aggregate is

$$A = \sqrt{(V^2 + H^2)} + \sqrt{(V^{1\,2} + H^{1\,2})}.$$

Each of the pressures denoted by P is a more or less variable quantity, and even when its variations of magnitude are neglected (as is the case in the following examples) its direction is reversed in each half revolution; so that in using algebra the components of P change from positive to negative. Separate calculations are to be made of the aggregate pressure A for each part of a revolution in which the changes of P cause A to have a different value; each value of A is to be multiplied by the fraction of a revolution during which it exists; then the products, being added together, will give the mean value of the aggregate pressure, neglecting the weight of the shaft. To take the weight of the shaft into account, divide it into two parts, inversely proportional to the distances of the centres of the two bearings from the centre of gravity of the shaft, and let W and W^1 be those parts. Then in the expressions for the pressures at the bearings $V + W)^2$ and $(V^1 + W^1)^2$ are to be put instead of V^2 and $V^{1\,2}$ respectively. The quantities in brackets are sums when V and V^1 are positive, that is, downward; and differences when V and V^1 are negative, that is, upward; and the change from positive to negative takes place at each half revolution; so that in taking the mean value of the aggregate pressure for every term in which the quantities in brackets are sums, there is a corresponding term in which they are differences. The consequence is that whichever of the quantities V and W, or V^1 and W^1, is small compared with the other, and in many cases, whichever is simply the smaller of the two, has a small or an insensible effect on the mean aggregate pressure, as has been already stated.

7. Examples.—The following examples are confined to very simple cases, being those which most commonly occur in practice. They consist of calculations whose results express values of the ratio borne by the aggregate pressures on the shaft journals to the aggregate pressures on the crank journals, which ratio, as already stated, expresses the ratio of shaft journal friction to crank journal friction, if the diameters of the journals and the coefficients of friction are the same. For brevity's sake, this ratio will be called comparative shaft friction. The weight of the shaft will be neglected, for the reasons formerly stated, except where the pressures at the shaft bearings, due to the forces at the crank bearings, vanish; when the shaft friction is that due simply to the weight of the shaft.

Case I.—One crank; one piston; crank between the two shaft bearings. Comparative shaft friction=1.

Case II.—One crank; one piston; crank beyond the two shaft bearings. Let $2b$ be the distance between the centres of the bearings; x, the distance of the centre of the crank bearing from a point midway between the shaft bearings, which in this

case is greater than b; then if P be the pressure at the crank bearing, the pressures at the shaft bearings are respectively

$$-\frac{P}{2}\left(\frac{x}{b}-1\right) \text{ and } +\frac{P}{2}\left(\frac{x}{b}+1\right)$$

and their aggregate is $P\frac{x}{b}$; so that we have comparative shaft friction $=\frac{x}{b}$. This ratio is greater than unity; showing the disadvantage in economy of power which arises from having the crank overhanging the shaft bearings.

CASE III.—One crank between the shaft bearings; 2 pistons, with rods at right angles. The efforts exerted by the 2 pistons being each $=P$, their aggregate is 2 P; their resultant is $P\sqrt{2}$; and consequently comparative shaft friction $=\frac{\sqrt{2}}{2}=.707$ nearly. This is a frequent arrangement in marine engines.

CASE IV.—One crank, between the shaft bearings; 3 pistons with rods making equal angles of 120 deg. The aggregate of the efforts exerted by the 3 pistons, is 3 P; their resultant is 2 P, and consequently comparative shaft friction $=\frac{2}{3}=$ .667 nearly. This is the arrangement of some paddle wheel engines.

CASE V.—One crank between the shaft bearings; a great many pistons, with rods making equal angles. Comparative shaft friction, as the number of pistons is increased, approximates to the limit $\frac{2}{\pi}=.637$ nearly; and this is the limit of the extent to which it is possible to diminish that ratio, when only one crank is used.

In the next class of cases there are supposed to be 2 cranks at equal distances, denoted by $\pm c$, from a point midway between the shaft bearings, whose distance apart from centre to centre is $2b$; and as before, the efforts exerted by the pistons are supposed to be equal. The shaft is further supposed to have no intermediate bearings between the cranks, or to exert no appreciable pressure on those bearings.

CASE VI.—Two cranks, making with each other an angle equal to the fraction n of a half revolution; 2 pistons, the rods parallel to each other. Aggregate of pressures at crank journals 2 P. In this case, during the fraction n of each half revolution, the efforts of the pistons are opposite; their resultant force is nothing; their resultant moment is $2\,P\,c$, and the aggregate pressure at the shaft journals $\frac{2\,P\,c}{b}$. During the remaining fraction $1-n$ of each half revolution the efforts of the pistons are parallel and in the same direction; their resultant force is 2 P; their resultant moment is nothing; and the aggregate pressure at the shaft journals is 2 P. Hence the comparative shaft friction is

$$n\frac{c}{b}+1-n.$$

The following are particular examples:

	Comparative shaft friction Any value of $\frac{c}{b}$ .... $\frac{c}{b}=$
(1) $n=\frac{1}{2}$, that is, cranks at right angles.....	$\frac{1}{2}\frac{c}{b}+\frac{1}{2}....\frac{3}{4}=.75$
(2) $n=\frac{3}{4}$, that is, cranks at 135 deg. apart.....	$\frac{3}{4}\frac{c}{b}+\frac{1}{4}....\frac{5}{8}=.625$
(3) $n=1$, that is, cranks opposite in direction...	$\frac{c}{b}$ .... $\frac{1}{2}=.500$

The first of these particular examples is the commonest of all arrangements of 2 cylinders comprehending ordinary pairs of single-cylindered engines, and the form of compound engine introduced by Nicholson, and improved by Cowper, when the distribution of the steam is such as to make the efforts on the two pistons equal. The second is an example of an arrangement used in some two-cylindered expansive engines, such as the later form of Craddock's, and Carrett and Marshall's, in order to have the motions of the pistons nearly contrary, and at the same time to have the power of turning the centre. The third is that form of compound engine which, when the efforts of the two pistons are equal, realizes the greatest economy in shaft friction possible with two cylinders only. It is deficient in the power of turning the centre, so that in steam vessels it is advisable to use such engines in pairs.

CASE VII.—Two cranks, between the shaft bearings, opposite in direction; 4 pistons, each crank driven by two piston rods at right angles to each other. The solution of this case is obtained by combining those of case III., and of the third example of case VI., that is to say, comparative shaft friction $=\sqrt{\frac{2}{2}-\frac{c}{b}}$. This

is nearly the arrangement in some pairs of compound marine engines, made by Messrs. Randolph, Elder & Co. The pairs of piston rods are not in every case exactly at right angles; to allow for this, let the angle which they make with each other be $n^1\,\pi$, being the fraction n^1 of a half revolution; then for the preceding expression substitute the following:

$$\frac{c}{2\,b}\left\{n^2\sqrt{(2-2\cos.\,n^1\pi)}+(1-n^1)\sqrt{2}+(2\cos.n^1\pi)\right\}$$

The result, when $n^1\,\pi$ is an oblique angle, is greater than when it is a right angle, but the difference for small obliquities is unimportant in practice.

Case VIII.—Three cranks, making equal angles of 120 deg.; 2 shaft bearings only with sensible pressure at the distance apart, b; the middle crank midway between the bearings; the other two at equal distances $\pm\,c$ from it, 3 pistons, with parallel rods. The aggregate of the pressures at the crank bearings being 3.P, their resultant force is at all times = P. The resultant moment is nothing when the two outer cranks are at the same side of the shaft, and 2 P c when they are at contrary sides, the latter being the case during two-thirds of each half revolution. The pressure at a given bearing has in the three successive thirds of each half revolution the three values

$$\tfrac{1}{2}\,P-P\,\frac{c}{b};\ \tfrac{1}{2}\,P;\ \text{and}\ \tfrac{1}{2}\,P+P\,\frac{c}{b}.$$

The aggregate of these pressures has one or other of the following values, according as $\frac{c}{b}$ is less or greater than $\frac{1}{2}$. If $\frac{c}{b}$ is less than $\frac{1}{2}$, P. If $\frac{c}{b}$ is greater than $\frac{1}{2}$, 2 P $\frac{c}{b}$ for two-thirds of each half revolution, and P for the remaining third. Hence we have for the comparative shaft friction:

If $\frac{c}{b}$ is less than $\frac{1}{2}$; $\frac{1}{3}$ = .333 nearly.

If $\frac{c}{b}$ is greater than one-half $\frac{4\,\frac{c}{b}+1}{9}$

This arrangement of cranks occurs in the 3-cylindered engines of Messrs. Maudslay; but as there are intermediate bearings between the cranks, the calculated result will not be realized unless the pressures at these bearings are insensible.

Case IX.—Three cranks between 2 shaft bearings; the 2 outer cranks opposite in direction to the middle crank; the 3 piston rods parallel; the efforts of the 2 outer pistons each equal to one-half of the efforts of the middle piston. Here there is a balance of efforts at all times, the resultant force and the resultant moment being each sensibly equal to nothing. The shaft friction is simply that due to the weight of the shaft. This arrangement realizes the greatest possible economy of power in the friction of the shaft journals. It was the invention of the late John Elder, who used it in compound expansive engines with the high-pressure cylinder in the middle, and a pair of low-pressure cylinders, one at each side. In order to turn the centre and give uniformity of action, he combined those 3-cylinder engines in pairs, with piston rods at right angles, acting on one set of 3 cranks, so that there were 6 cylinders in all. Such was the construction of the engines designed by Elder for H. M. S. Constance; and upon trial they showed an economy of power, over and above that due to expansion, which can be accounted for only by the smallness of the journal friction.

8. Remarks.—It appears from the preceding examples that various degrees of economy in the friction of the engine shaft journals may be attained by means of suitable forms of engine; the higher degrees of economy requiring more numerous cylinders, and consequently greater cost and the highest possible degree, 3 cylinders for a single engine, and 6 for a pair of engines. It may not be always advisable to increase the number of cylinders for the sole purpose of diminishing friction; but when, for other objects, such as high rates of expansion, many cylinders are used, it is very important to know how to arrange them so that they may, by the balance of efforts of the pistons, realize the greatest economy of friction consistent with their number.

W. J. M. R.

Sassafras-oil.—In Richmond, Va., a firm of colored persons has for 2 years manufactured sassafras-oil on a large scale. The root is purchased at the factory at the rate of 30 cents per 100 lbs., and 40,000 lbs. are used per week, producing two per cent., or 800 lbs. of unrectified oil. The oil is used for scenting toilet-soaps, flavoring tobacco, etc.

EXPERIMENTS ON THE STRENGTH OF MATERIALS.

From "The Builder."

A variety of experiments on the strength of materials, were made by Mr. Kirkaldy for the works of the new bridge at Blackfriars, and were referred to by Mr. Carr, in his paper. Some of these experiments gave results as follows:

Bricks, in Piers Four Courses High.

Description of Bricks.	Size of Pier in Bricks.	Mortar.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
Common stock recessed	1½ by 1½	Lias lime	17	27
Ditto ditto	1½ by 1½	Ditto	21	30
Red Bricks, machine-made	1½ by 1½	Ditto	20	40
Ditto hand-made	1½ by 1½	Ditto	20	36
Galt	1½ by 1½	Roman cement	24	59
Ditto	1 by 1	Ditto	54	72
Clark's Sudbury machine	1 by 1	Portland	49	76
Uxbridge red, hand-made	1 by 1	Ditto	44	53

Stone Cubes of Two Inches bedded on Sheet Lead.

Description.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
De Lank granite, Cornish	283	363
Ditto ditto	279	....
Ditto ditto	349	377
Guernsey	276	330
Ditto	761	1,150
Cheesewring, Cornish	295	403
Ditto ditto	194	322
Portland	106	155

A small polished column of red Mull granite, length 6 in., diameter nearly 3 in., was cut through the middle, and the cut faces accurately ground; when tested packings of pine were placed at each end, and the surfaces, where cut in two, were put together with a little boiled oil. This 3-in. column bore a strain of 60 tons, or 8¾ tons per sq. in., 1,260 tons per sq. ft., or the weight of a column 16,380 ft. high.

An experiment was made to test the effect of a small area of iron pressing on a surface of De Lank granite. A cube of 1-in. wrought iron was placed between 2 blocks of granite, 6 in. by 6 in. by 5 in.; a packing of ¼ in. of pine was placed between the granite and the machine, and between the iron cube and granite. One of the blocks was split with a pressure of 50 tons; the block which was not injured was again submitted to pressure with another cube; it was then fractured with a pressure of 52 tons. The iron cubes were reduced in thickness $\frac{1}{6}$, with an equivalent lateral extension.

It was desired to see what would be the effect of great pressure on the skewback stones. A stone was worked ¼ scale, and a corresponding portion of arch rib made; the two were bedded together with lead run in between, in the same manner as proposed for the arches themselves. They were then gradually submitted to a pressure of 200 tons, but without any effect except extrusion of the lead; the iron, however, with 18 tons per inch, seemed to have quite as much as it could carry. Being all to ¼ scale, the area under pressure was $\frac{1}{16}$ the real size; the pressure was therefore equivalent to 3,200 tons in the bridge itself, the actual pressure in work being under 400 tons.

Gun-metal cramps were also tested, the result being the rejection of several mixtures of metal submitted by the contractors, and an increase of strength obtained from 17,519 lbs. per in. area to 28,883 lbs. (7¾ to nearly 13 tons).

In order to test the strength of timber used as struts, 2 whole balk, 20 ft. in length and 13 in. square, were submitted to end compression. The red timber crippled with 138 tons, or 112 tons per ft. area, and the white with 147 tons, or 126 tons per foot area, the reduction in length being in one case $\frac{5}{8}$ in., in the other ½ in.

Specimens of the fractures are now exhibited.

Portland cement was also tested, the standard of the Metropolitan Board of Works being adopted, 110 lbs. weight per bushel, and 500 lbs. tensile power on $2\frac{1}{4}$ in. area; some results obtained were as high as 733 lbs. on the $2\frac{1}{4}$ in.

Experiments were made on the iron from time to time, but the specified strength was not fully attained; it was, perhaps, pitched rather too high for such work. The extension of $\frac{1}{12\frac{1}{5}}$ part of the length was given by strains varying from 13 tons to 15 tons instead of 16 tons, but even with this, the elastic limit is just about 4 times the working load, which is ample allowance for safety, taking into account a very large deterioration from time and corrosion.

The above figures are stated in round numbers. The results, as given by Mr. Kirkaldy, are in every respect most accurate and minute, but high numbers of pounds instead of tons, and long decimals, are not suitable for such a sketch as this.

EXPLOSIVE COMPOUNDS.

From "Engineering."

DYNAMITE AND ITS MANUFACTURE.

Having in previous articles considered the progress made during the past 5 years in gunpowder and gun-cotton, we have in the next place to notice dynamite, one of the most formidable, and at one time one of the most promising, rivals of gunpowder for special purposes. The base of dynamite is nitro-glycerine, which ranks amongst the remarkable materials employed to replace gunpowder as destructive agents. It was discovered by Sobrero in 1847, and is produced by adding glycerine in successive small quantities to a mixture of 1 volume of nitric acid of sp. gr. 1.43, and 2 volumes of sulphuric acid of sp. gr. 1.83. The acid is cooled artificially during the addition of the glycerine and the mixture is afterwards poured into water, when an amber colored fluid separates from it. This fluid is insoluble in water, possesses no odor, but has a sweet pungent flavor and is very poisonous, a minute portion placed on the tongue producing a violent headache. The liquid has a specific gravity of 1.6, and solidifies at 5 deg. C. or 40 deg. Fahr. The properties of nitro-glycerine are tolerably well known; it simply burns when flame is applied; if paper be saturated with it and struck sharply a somewhat violent detonation is produced. In 1864 Mr. Alfred Nobel, a Swedish engineer, applied nitro-glycerine to the purposes of blasting. He first used gunpowder saturated with nitro-glycerine, which burned more brightly in the open air than unsaturated gunpowder, but its destructive effect under confinement was from 4 to 6 times that of pure powder. The oil itself cannot be exploded by an ordinary fuze, so Mr. Nobel attached a small charge of gunpowder to the end of the fuze and by this means the explosion of the nitro-glycerine was effected.

But although a very useful agent, nitro-glycerine often proved itself a highly dangerous one. The frequent and fatal accidents which occurred with it between the date of its practical application and the year 1868, will doubtless be fresh in the memory of our readers. On the 3d of April, 1866, the West India Company's steamer, European, whilst unloading at Aspinwall, had her decks ripped up and her sides blown out, whilst a wharf 400 ft. long was literally torn to pieces, about 50 persons being killed and a number wounded, by an explosion of nitro-glycerine on board the vessel. On the 16th of the same month, 2 cases of the oil arrived at San Francisco by the Pacific mail steamer and were taken into that city, where they were no sooner deposited than they exploded, the results proving terribly fatal to human life. In Sydney, New South Wales, too, about the same time, 2 packages of the oil exploded in a store in Bridge street, with disastrous results, whilst at home later still we have had two fatal explosions, one at Cwm-y-glo, near Carnarvon, and the other in the suburbs of Newcastle. Two other cases of explosion occur to us; one in which a carman greased the wheels of his cart with nitro-glycerine, and the other where the nitro-glycerine was frozen, and the workmen placed lumps of it on a stove to thaw. The cause of the explosions was here very apparent, as it also

was in the case of the Cwm-y-glo accident, where the packages of nitro-glycerine were being carted to the slate quarries, a package having been placed loosely on the front-board of one of the carts. This package doubtless fell off the cart, and, exploding, caused the explosion of the remainder of the packages. Although there is no proof of the manner in which the other accidents were actually caused, it is tolerably certain that a blow must have been in some way or other administered to the cases containing the oil. Therefore, since nitro-glycerine has been largely used in the past with a comparatively small number of accidents, and since its manufacture is still carried on upon a large scale for conversion into dynamite, it is only fair to assume that with reasonable care in manipulation, accidents with nitro-glycerine would not occur.

The accidents, however, which resulted from the use of nitro-glycerine, led Mr. Nobel to experiment with the material in various ways with the view of rendering it less dangerous. The first result was the discovery that it could be rendered non-explosive, either from percussion or heat, by mixing with it methylic alcohol. When required for use, water was added, which absorbed the spirit and allowed the oil to sink to the bottom of the vessel, whence it was drawn off for use, its explosive nature being restored. This method of protecting the treacherous oil was adopted to some extent; it answered the purpose during storage or transit, but, at the time of use, all the dangerous properties of the oil were present, and accidents arising from carelessness continued to occur. Mr. Nobel, satisfied that the protective arrangement was only half a solution of the difficulty, continued his researches, and early in 1868, he succeeded in effecting a new combination in which nitro-glycerine was rendered perfectly innocuous except under the actual conditions of work. This desirable end was attained by mixing the oil with silica—fine gravel for instance—the compound resembling in appearance course brown sugar, a little damp. To this substance Mr. Nobel gave the expressive name of "dynamite," and with it he made a series of experiments at the Merstham Greystone Lime Works, in July, 1868. The object of these experiments was to illustrate the safe and harmless character of dynamite under any other conditions save those of actual work, and to demonstrate its resistless energy when fired by a percussion fuze. The experiments were thoroughly successful, and proved beyond a doubt that dynamite could not be exploded by concussion, and that if placed on a fire or ignited in the ordinary way, it only burned slowly out. When, however it was fired by a percussion fuze, even in the open air, all its intensity of power was fully developed, and was increased by exploding it in water or under conditions of confinement.

The most severe tests for safety failed to show that any danger was present in this material, whilst, on the other hand, there was no condition under which its violence was not fully developed when fired with a detonating fuze. One out of many illustrations of its power is worthy of notice here. A cylindrical block of wrought iron, 12½ in. high and 10½ in. in diameter, and having a 1 in. hole bored through its centre, was used. The bore hole was lightly filled with dynamite and fired by a time fuze, the charge not being plugged. The explosion split the cylinder in two equal halves longitudinally to the axis of the bore, one-half being bedded in a grass bank 80 ft. away from the place where the charge was fired, and the other half being found about 50 ft. in an opposite direction, having been stopped by a mass of limestone rock. The iron showed a clean split, the bore-hole being enlarged to 1¾ in. at the centre, showing the enormous compression the metal had undergone at that point. A charge wrapped in thin paper and fired under water exhibited the same resistless power, and demonstrated the fact that dynamite is unaffected by moisture. The only point of doubt that arose in our mind at the time of witnessing the experiments, was as to whether any mechanical separation of the silica from the oil or chemical change in the compound could occur in the course of time which would render dynamite as dangerous as nitro-glycerine. Mr. Nobel, however, stated that there was no fear of such an occurrence, inasmuch as he had had dynamite in store for very lengthened periods subject to extremes of temperature—some very high—and that it retained its original condition under some very trying tests.

The stability of dynamite has been practically confirmed by extensive and

daily use in the mines on the Continent, and by a limited use in England, as well as by the large quantities which are stored at the factories. Beyond this, the most careful investigation has shown that there is not the slightest ground for apprehension on that score. Under continued exposure to the direct rays of the sun during the whole of the summer of 1868—an exceptionally hot one—not the slightest chemical change could be detected. The same results were obtained with a parcel of dynamite exposed for 40 days to a temperature varying between 150 deg. and 200 deg. Fahr. All nitrated, or rather hypo-nitrated organic compounds are liable to spontaneous decomposition—or what is understood by this hackneyed and ridiculous term—unless they are completely rid of free adhering nitric acid. The reason is that the free acid produces a local decomposition which sets hypo-nitric acid free, the latter producing a new local decomposition, and so on until sufficient heat is evolved to set fire to the compound. There is no difficulty in ridding dynamite of free acid; but in the case of cotton, or any other fibrous substance, the utmost care is required, as free acid will adhere in spite of repeated washing. It will be seen that the method of percussively exploding the charges of dynamite adopted by Mr. Nobel is precisely similar to that devised by Mr. Brown for exploding gun-cotton, as described in a previous article upon the latter material. It is, however, but fair to state that Mr. Nobel used his percussion fuzes at the Merstham experiments, to which reference has been made, in July, 1868, whilst the experiments with gun-cotton exploded in the same way, were not carried out until the 22d of January, 1869.

It is generally conceived that nitro-glycerine, and consequently dynamite, is more dangerous and more easily exploded when in a frozen state than when liquid. But this conception is erroneous, inasmuch as it is really difficult to explode it when frozen, and we have a case in point to prove this. A charge of nitro-glycerine had become frozen in a hole at a quarry near Bangor, and was fired 3 times with gunpowder without being exploded. A small cartridge containing about ½ oz. of the liquid oil was then inserted in the blast hole on the top of the frozen charge, and on being fired, exploded the whole charge, which did its work most effectually. Some experiments made with frozen dynamite tend to prove that it cannot be made to explode even by percussive fire. Percussion fuzes have been exploded in it, but they have only either blown it away in fragments, or have set it on fire, so that it burned quietly away. These facts at once silence any theoretical objections which may be raised to this compound on the score of its explosiveness whilst in a frozen condition.

There can be no question as to the real value of dynamite as an explosive for mining purposes. This value is fully recognized in Germany, where depots have been established in every mining district throughout the country. A firm at Cologne, who are the largest manufacturers of blasting powder in Western Prussia, have long been converts to dynamite, and have taken up its agency. In Sweden and Norway the consumption is very large, as it is also in the United States and California. It would doubtless appear strange that dynamite—possessing as it does so many and great advantages—should be so little known and so very much less used in England. The truth is that dynamite would undoubtedly have had as great a run in England as on the Continent, had it not been that a short Act was quietly smuggled through Parliament during the Session of 1869. It is known as the "Nitro-glycerine Act," and it virtually prohibits the importation, exportation, manufacture, sale, or even possession of "every substance having nitro-glycerine in any form as one of its component parts or ingredients." The Act is a very snug little affair, and if it was not promoted by the gun-cotton party, why it ought to have been; it cannot fail, however, to afford them much satisfaction. It will thus be seen that extraordinary impediments have been thrown in the way of the use of dynamite in this country, and the consequence is that not more than 20 tons have been sold in Great Britain since the Act was passed. Messrs. Webb & Co., of Bangor, are the agents for Mr. Nobel—whose factory is at Lauenberg—but they inform us they are literally doing nothing, although they have constant applications for the material. At several mines where dynamite has been tried, the managers are constantly

pressing for further supplies, but of course to no purpose.

With regard to the power of dynamite, we may observe that its destructive action is estimated to be about 10 times that of an equal weight of gunpowder. If, therefore, we take the average work done by 1 lb. of gunpowder at 32,832 lbs. —an average obtained from actual practice in 6 different places, and in various kinds of rock—we get 328,320 lbs., or about 146½ tons, as the work done by 1 lb. of dynamite. Hence, although its cost is greater than that of blasting powder, its use is attended with great economy. We have ascertained this economy to be in one mine in Cornwall as much as 50 per cent., whilst it is stated that the St. John del Rey Mining Company doubled their workings at ⅔ the cost of gunpowder. We are also informed that this same company saves £1,000 per month by the use of dynamite as against gunpowder. The greatest economy results from its use in hard rock, a considerable saving being effected by its means in the labor of the miners, and in the time occupied in performing a given amount of work, as much fewer and smaller blast holes are required than when gunpowder is employed. We are not aware that any comparative experiments have been made with dynamite and gun-cotton, and which would afford data as to their relative power. Taking, however, the results of the Merstham trials already referred to, and those of the gun-cotton experiments in January, 1869, we should certainly say that dynamite was the stronger of the two. Our reasons for this conclusion are founded upon the circumstances that at the latter experiments 5 lbs. of gun-cotton failed to more than shake a palisade, which we think 5 lbs. of dynamite would have demolished. This question, however, can only be settled by comparative experiments, which at present there is but little chance of seeing carried out, at any rate in England.

The most recent modifications introduced by Mr. Nobel in the manufacture of explosive compounds, into the composition of which nitro-glycerine enters, are to be found in two kinds of blasting powder, which were introduced by him towards the close of last year. The composition of the two types of this powder is as follows: No. 1. Pulverized nitrate of barytes, 68 parts; charcoal of light texture, 12 parts; nitro-glycerine, 20 parts. No. 2. Pulverized nitrate of barytes, 70 parts; powdered resin, 10 parts; and nitro-glycerine, 20 parts. The charcoal is carbonized at a low temperature, and consequently still contains hydrogen. An addition of from 5 to 8 per cent. of sulphur to either of the above mixtures gives a powder which fires more briskly, but, at the same time, it increases the danger in the manufacture, carriage, and application of the powder. The method of using these powders is to place them in cartridge cases, the powder being covered with a little mercurial or other fulminate before the case is closed and primed. The cartridge is placed in the bore-hole and tamped in the usual way, and is fired either by a fuze or by an electric wire. The fulminate, acting on the nitro-glycerine, ignites the whole charge instantaneously.

In our opening remarks we referred to the dangerous character of nitro-glycerine, as illustrated by several catastrophes. In concluding, we would bear testimony to the comparatively harmless nature of dynamite, as evidenced by the Merstham experiments, and further by a circumstance which came to our knowledge in 1868. In that year a tremendous explosion of nitro-glycerine occurred at Mr. Nobel's factory at Stockholm, which destroyed the works. Close by was a store of dynamite, which, after the explosion, was found scattered about in all directions, but none appears to have been exploded. The further evidence of the safety of dynamite is of a negative character, and consists in the absence of any record of accident either in manufacture, storage, or transport. Two accidents have happened with dynamite while in use in mines, but they arose from sheer carelessness. In one instance the tamping was incautiously removed after a misfire, an operation which ought not to be allowed in any case; and in the other a half-witted miner, having heard that dynamite burned harmlessly in the air, lighted the fuze of a charged cartridge, and held it in his hand until it exploded. A third accident of a special character occurred at Wigan, where a workman was blasting a large mass of iron on a very hot day and with loose dynamite, not confined in paper cartridges. He fired the charge, which was not strong enough

to break up the iron, and he forthwith commenced to recharge the hole with dynamite. While ramming the powder down with a wooden rammer it exploded, blowing the rammer out of the man's hand, and injuring him. He was by no means seriously injured, and would have recovered but for the circumstance that one or two small splinters from the rammer had entered his arm, and being saturated with nitro-glycerine they poisoned the flesh, and the man died in a fortnight. Three men were standing by at the time of the accident, one of whom had 8 lbs. of dynamite in a bag with him. The dynamite took fire and burned slowly away, slightly scorching the man who was holding it, but not hurting the other two men.

There can be no doubt that the explosion arose from the extreme heat of the iron consequent on the explosion of the first charge, the hot sun rendering the dynamite more sensitive, the ramming down of the powder while in this sensitive state causing it to be fired. This, in fact, was subsequently proved to be so by Mr. Webb—to whom we have already alluded—who took a lump of hot coke and placed some loose dynamite on it. The dynamite soon began to smoke, and after it had smoked awhile Mr. Webb touched it with a rod, and it immediately disappeared with a kind of semi-explosion. The experiment was repeated several times with the same results, and the accident would not have occurred if the bore-hole in the iron had been sponged out. These are the only accidents we can discover, and they are such as must and will occur, however safe the explosive may be to handle, where carelessness or thoughtlessness exists.

THE VENTILATION OF UNWHOLESOME MANUFACTORIES.

From "The Engineer."

Some time ago M. Charles de Freycinet, *Ingénieur des Mines*, was directed by the then French Imperial Government to visit the most important manufactories in England, France, Germany, and Belgium, in order to report upon the means actually adopted in the more unwholesome operations for maintaining the health of the people employed. The results of his lengthy examination, apparently extended over several years, have been given in four very important reports, to which our attention has only lately been directed, and from which we propose to make some extracts, more particularly referring to ventilation, or renewal of the air, as a means of getting rid of injurious vapors and gases, or also of substances in a state of minute subdivision. A general and elementary means of preventing the infection of the air by deleterious vapors consists in the use of very high chimneys, which are generally acknowledged to be all the more efficacious for this purpose the higher they are; and that this is the case, not merely at a given point, but in the entirety of the circle of their action, all the new coke ovens erected in Belgium are now officially required to disengage their gases into chimneys at least 45 ft. to 60 ft. in height. The application of tall chimneys receiving the gas from a group of coke ovens has notoriously effected quite a change in the county of Durham, where sometimes as many as 1,000 coke ovens are found congregated together. In the wine districts of France the smoke from lime and brick kilns has been found to injure the quality of the grapes, giving the wine made therefrom a sooty taste; so that unfortunate burners have been adjudged to pay considerable damages to the owners of neighboring vineyards. Tall chimneys have thus been made a necessity, and the nuisance caused to the town of St. Etienne by the numerous coke ovens has been completely obviated simply by their use.

Ventilation by means of fans, acting either in the buildings or directly on the apparatus of manufacture, is in general use in French factories for the preparation of white lead, the torrification of tobacco, dressing of leather, and in woollen or cotton manufactories. The infection of the general atmosphere is prevented by the use of chimneys and of condensation by water of noxious gases. In the preparation of soda, high towers of masonry, filled with coke, are employed for condensing the fumes. It is well known that workmen silvering mirrors are liable to

mercurial trembling produced by the vapors. At Saint Gobain, Cirey, and Chauny, near Paris, the men are only employed at this work twice, or, at the most, thrice a week. All the windows are kept open in the wide and well-ventilated workshop. The flannel rubbers by which the mercury is spread over the tinfoil are fitted with handles nearly 4 ft. long. The mercury is kept in close cases, and the cloths through which it is passed in order to get purified are not beaten in the open air, but by a beater contained in a hermetically closed casing. Gilding with mercury, as is done by Messrs. Bonin & Co., of Paris, is rendered safer by covering the fire intended to vaporize the mercury by means of a glazed dome surmounted by an open chimney. The man works by passing his hands under the casing, which extends below his chest. The workshop is also kept well supplied with fresh air. No means are said to have yet been discovered for rendering the manufacture of chromate of potash a wholesome operation. At M. Clouet's, of Havre, most of the men suffer from an actual perforation of the nasal membrane, which seems to be due to the suspension of particles of chromate in the air. Another very unsalubrious manufacture is that of quinine, which causes singular effects on persons brought within its influence. In both cases, however—and certainly in the latter, as we shall see by an instance further on—preventive means can be adopted. Another unwholesome and laborious operation, is that of dressing millstones by hand—a process now much facilitated by the use of the modern diamond dressing machines. The working population of La Ferté-sous-Jouarre, the well-known quarry of French burr millstones, is said to be decimated by the considerable disengagement of stone and steel-dust which takes place in dressing the stones. Ten years or so of work of this kind is said to often result in mortal disorders. The very fine charcoal powder used by bronze metal founders to dust their moulds is another instance of the insalubrious effects of fine dust mingling with the air; but for such moulds for bronze metal work the use of potato-flour instead of charcoal-dust has generalized itself in Paris with very happy results in this way. The mills of M. Leroux, of Rennes, for grinding up bark, are fitted with exhaust fans and a sort of stive-room for gathering up the dust, which is considered, at equal weights, to be more powerful than common tan of the ordinary size. In the cotton-spinning factory of M. Octave Fauquet, at Oisel, the principal room, 9,000 metres in area, devoted to carding and spinning, is built in a peculiar way, with the triple intention of obtaining a uniform temperature, carrying off the impurities, and keeping up a certain moisture in the air. In order to prevent variations in the temperature of the roofing, due to changes in the weather, the surface of the arches forming the ceiling was built up with ordinary glass bottles, placed alternately with the bigger and the smaller ends in the direction perpendicular to the surfaces of the arches aforesaid. The empty spaces were filled in with mortar; and, on drawing out the bottles, there only remained a light and, so to say, spongy shell. On this was laid a continuous covering of plaster, and by this means a double ceiling was obtained, consisting of a mattress of air confined in a multitude of cells. All the double skylights are set in this ceiling. The air is renewed and the impurities are expelled by means of two large fans placed in a subterranean gallery. It is the fan near the carding machines that is most used to expel the dust. The circulation of the air is obtained by means of a system of conduits arranged under the flooring and opening into 30 gridded orifices. The moisture is obtained by introducing a spray of cold water into the gallery used for injecting the air. The arrangement is stated by M. de Freycinet to be a perfect success. In cigar factories it is not required to keep up a uniform temperature ; and there is also much less dust than in cotton-spinning factories. It is, however, necessary to get rid of the emanations from the moistened tobacco and from the numerous persons engaged in manufacturing the cigars. In works at Bercy, Nantes and Chateauroux, the air is sucked by fans from the outside; it circulates between the joists of the flooring on traversing the casings of the stove, where it gets heated in winter ; 8 cubic metres of fresh air per hour are allowed per person. Each workshop has 4 heating stoves. Other conduits, similar to those of admission, are led to exhaust chimneys over the roof. At M. Orsat's, of Clichy, white lead is ground between pairs of stones,

the casing of which communicates with an exhaust fan. At Messrs. Engler & Krauss', of Paris, who use lead paste for enamelling insulating brackets of telegraphic wires, the enamel is ground up in hermetically closed mills. The chambers for manufacturing chloride of lime at the works of Mr. Charles Kestner, of Thann, communicate by a leaden pipe with the chimney. One or 2 hours before the entry of the workmen, a valve is opened at the same time as the doors. Suction sets up, and the gas is carried off by the chimney. The crucible furnaces for melting copper at the works of M. Maurel, of Marseilles, are placed in communication with the chimney of the steam boilers, which very effectually ventilates them. At the lead foundry of M. Lepau, of Lille, each of the melting furnaces is covered by a hood, fitted with a register, leading to a conduit opening under the ashpit of the steam boilers, so that communication can be cut off when not at work. The metalliferous vapors are thus thoroughly exhausted away. A somewhat similar process is employed by Messrs. Eschgar, Mesdach & Co., at Biache Saint-Vaast. M. Lepau also condenses the fumes; as the different exhaust tubes open into a chamber underground in communication with the steam boiler ashpits.

Speaking generally, very happy effects result in factories for treating mineral oils, and other fatty substances, varnishes, or for distilling wood, or sulphuretted hydrogen, by leading the vapors to the steam boiler furnaces to be there consumed. This is applicable in nearly all operations exercised on organic substances, and a considerable saving of fuel is often the result. For instance, at the soap-boiling works of M. Evrard, at Douai, the pans are fitted with a cast-iron semicylindrical cover, movable round a hinge, which can be raised more or less, as required. This cover is pierced with a hole by which the vapors can escape under the furnaces of the steam boilers; and at its end, the exhaust is intensified by a jet of steam. During the greater part of the time the cover is down, but when it has to be slightly raised for the introduction of the workman's stirrer, a cloth is lowered over the opening.

In Germany, and often under the stimulus of governmental interference, some very scientific mechanical and chemical means are adopted for preventing or carrying off injurious emanations. At Aix-la-Chapelle, the Prussian authorities have absolutely prohibited the grinding of needles unless the apparatus be furnished with a fan for exhausting away the fine particles of metal and stone thrown off in dry grinding. The Government requirements have also evolved two new machines for holding the needles mechanically. In the works of M. Schumacher, of Aix-la-Chapelle, for making steel pins, all the grindstones are fitted with fans. At M. Merck's pharmaceutical works at Darmstadt, where the poisonous belladonna is ground up in large quantities, a large bell, tightly jointed, suspended by chains from the ceiling, is lowered down on the mill after it has been charged with the belladonna, and is only raised up again when the grinding operation has been completed and all the dust has had time to settle. Experience has shown that this bell should be even without doors in its sides, as, whatever care may be taken, the fine powder still manages to pass through. At the works of M. Piret Pauchet, of Namur, Belgium, tan bark for tanners is ground up in three horizontal pairs of stones. The substance is introduced by a hole in the thickness of the upper stone, and each apparatus is contained in a metallic casing, to which is fitted the supply tube for the bark. Another tube communicates with a powerful fan, which exhausts the fine dust and propels it into a funnel on an upper story. At chemical works at Mannheim, managed by M. Gundelach, the men required to repair the leaden chambers for the sulphuric acid, or for chloride of lime, are covered with a sort of close helmet, supplied with air from an air pump through a flexible tube. This is also done at Worms and at Heilbronn.

The great extension of manufactures in Belgium, also coupled with a pretty stringent Government interference, have forced factory owners to have recourse to many ingenious means for obviating nuisances to the adjoining neighborhoods. At the works for the concentration of sulphuric acid, held by M. de Hemptinne, of Molenbeck-Saint-Jean, near Brussels, the platinum retort is cased in with masonry. The dome is pierced with a large hole covered by an hermetically closed plate of lead. Within the space thus formed between the retort and its covering is in-

serted a leaden pipe carrying off the vapors into the chimney. At the large paper mill of M. Godin, of Huy, where the coarsest rags are bleached by means of chlorine gas, the gas is led into stone cases, air-tight, which can be put into communication with a central chamber about 30 ft. high, and by which a powerful suction can be set up. At Ghent, and also Dusseldorf, whitelead is ground up with oil or water, in order to prevent the evolution of its injurious dust. White-lead is used in bleaching lace, and so much disease was thus caused amongst the lace workers, that the Belgian Government raised the question whether its use for this purpose should be abolished. One process now used consists in beating the lace inside a casing hermetically closed.

In the manufacture of ultramarine, by M. Leverkus, of Opladen, it is ground up within closed apparatus containing fans. As already observed, a singular disease affects the workmen preparing quinine and its sulphate—so much used as a tonic medicine. Herr Zimmer, at Sachsenhausen, near Frankfort, grinds up the bark in a moistened state, the ground up materials being afterwards treated in closed casings. In purifying the raw sulphate, the evaporating pans are kept in a distinct workshop, and under a covering fitted with an exhausting chimney. Generally, the different operations are carried on by self-acting machinery. At the establishment of M. de Roubaix, near Antwerp, for the manufacture of phosphoric matches, the five separate buildings in which are carried on the successive operations are all ventilated by means of a large central chimney, receiving the fire gases from the steam boilers, and, if necessary, from a special furnace. A large underground channel runs along the opposite sides of each building, and opens into the chimney. Wherever the phosphorus is placed, an opening in the wall is made to communicate by a pipe with the subterranean channel, and thus leads away the deleterious vapor ; the arrangements made for taking up the vapor vary with the nature of the operation. Thus, a large flat bell, set near the ground, is placed over the spot where the paste is formed. In the woollen factory of MM. Hauzem, Gerard, & Co., of Verviers, the combing machines are set up in a separate building, and are provided with fans. In the spinning mill two powerful fans exhaust the air from the two ends, while several openings in the flooring allow the entry of fresh air. The woollen stuffs are spread on a grid covering a large casing closed up at its other sides. A fan powerfully exhausts from the inside of the casing, while a current of hot air is led against the ceiling of the building. By this ingenious plan the workmen are quite free from the unwholesome atmosphere generally present where the vapors are allowed to disengage freely. At Ypres, the lime which has served for purifying lighting gas is, on cleaning out the cases, immediately mixed with the ashes from the fires, which process at once destroys all smell ; and the mixture, kept in a well ventilated passage, causes no inconvenience, and is sold as manure.

In England, the manufacturers themselves holding, in many instances, the local government in their own hands, sanitary ventilation is too often neglected ; though more favorable cases can be cited. Thus, fans are used at Messrs. Joseph Rodgers & Sons, of Sheffield, and at Messrs. Thomas & Sons, of Redditch, to exhaust away the fine particles of metal produced in the process of dry-grinding cutlery and needles respectively. The exhaust of the factory chimney used is for the same purpose at some other places. At the candle factory of Messrs. Price, of Battersea, the storehouse for the manufactured goods is ventilated by means of a cylindrical roof of thin plate, opening at the top into a number of small chimneys. The plate roof, getting heated by the least sunshine, a very powerful draught is created. The resulting effluvia on the river Thames are, however, sometimes very powerful. Manure factories in England are generally ventilated by chimneys of extraordinary height. In glue factories the vapors are burnt in the furnaces. At the manufactory of Mr. Crossfield, of St. Helens, the chambers wherein the chloride of lime is made are in communication by an exhaust pipe with the chimney of the works. On opening an opposite door a current of air is set up, and the chlorine in excess is quickly exhausted. At Messrs. Elkington's, of Birmingham, the air of the workshop where the silvering is carried on is sometimes filled with the considerable amount of hydrogen disengaged by the decomposition of

the water by the galvanic piles. It is got rid of by means of a column ventilator opening above the roof of the building. In the shops where the silvered or gilded articles are cleaned the acid vapors are disengaged under domes in communication with one of the large chimneys, or with a pipe within which burns a strong gas flame.

Generally, it is by artificial ventilation that the preparation of leather, the grinding of needles, the manufacture of phosphorus matches, the spinning of textile fabrics, the grinding of bark, and in general operations giving rise to the evolution of vapors or of dust, have been rendered much more wholesome. In other instances, such as the manufacture of fulminate of mercury and the concentration of sulphuric acid, preventive modifications in the manufacture have rendered actual ventilation unnecessary. Enamelling iron plate, for instance, is a very unwholesome operation, especially when the enamel embodies lead, and even arsenic; but metal enamelling pastes and powders quite free from lead are now getting into use. Analagous to this is the substitution of amorphous phosphorus for the white kind.

THE GREAT AUSTRALIAN TELEGRAPH.

From "Engineering."

The last advices from South Australia appear to show that there has been a hitch in the development of the Great Australian Telegraph line. Bravely as the enterprise has been entered upon and prosecuted, it has been found to present greater difficulties than had been anticipated in the first instance. Still the latest tidings which have come to hand with respect to the great work are not calculated to induce a feeling of despair as to its future, but merely show that the South Australian authorities have committed themselves to a more arduous task than had been at first imagined. The South Australian Government vessel, the Gulnare, while on her way from Palmerston to the Roper river, struck on a reef near the Verdon Islands, a group lying between Melville Island and Adam Bay, and within a comparatively short distance of Port Darwin. She contrived to return to Port Darwin, but on arriving there she was condemned, and the Bengal was chartered to take her place. Mr. Patterson, one of the superintendents concerned in the development of the line, had also reported loss of stock in pushing his way from the Catherine to the Roper, and had requested the Colonial Government to send reinforcements to the Roper. The South Australian Cabinet had accordingly met, and had resolved upon sending a steamer and also a sailing vessel, carrying additional horses and wagons, with their drivers and all necessary supplies, as requested. Mr. Todd, the South Australian Postmaster General and Telegraph Superintendent, was to leave by the steamer, in order to personally direct the completion of the great line and its opening for traffic.

The difficulties which have arisen occur at the northern end of the great line; the intelligence which has come to hand as to the central sections is relatively satisfactory. Two communications have been received in Adelaide, for instance, from Section E. The first, dated from the Third Main Camp on Gilbert's Creek, on September 1, refers to the fact that 61 miles of poles had been erected, but the ugly fact had been established that the line would have to pass for a considerable distance through country destitute of surface water; a well had been sunk, and water had been obtained at 17 ft., but it had not been ascertained whether the supply was likely to be permanent. This scanty water supply has always been considered to be the great drawback to Central Australia, although in some seasons there may be a greater quantity of moisture available than at other less favored periods. Another letter, dated September 20, states that the camp had been shifted to Tenant's Creek, latitude 19 deg. 33 min.; the work was then progressing well, and about 75 miles of poles were expected to be put up shortly. The communication is from Mr. Roberts, the second in command, and it states that Mr. Harvey has been well-sinking, and had struck water at 20 ft. Mr. Burt had been

sent on to Newcastle waters to communicate with the Port Darwin end, news not having at that time arrived in respect to the Northern Territory sections. Several thunder-storms had occurred, and it is noted that Mr. Millner had passed beyond the end of Section E with his sheep, and was supposed to have reached the Newcastle waters. A previous account mentions that in passing the Davenport range, Mr. Millner lost 1,200 or 1,400 sheep by poison.

As regards the southern section—that is, the section nearest to Adelaide—it appears, according to the last advices, to have moved on well. At the date of the last reports the whole of Mr. Bagot's contract was poled. North of the Gums there were only 10 poles to the mile, but the contractor's men were engaged in putting up the intermediate ones, and this had been done for 28 miles north of the Peake. A party was busily erecting the wire, working from the northernmost end back to the Peake, and another lot of men had wired from Port Augusta to within 27 miles of Mount Margaret. A third party was at work planting the intermediate poles on the portion between the Gums and the Peake. Considerable progress was thus being made upon the whole, with what was expected to be the latest portion of the line—that is, the part between Port Augusta and the end of Section E. The operators for the interior stations arrived at the Peake all well on November the 6th, and they were to start forward in a few days. Rains fell early in November, and these were expected to greatly facilitate the construction and opening of the southern portion of the line. By Christmas day, in fact, it was anticipated that telegraphic communication would be established as far as the Macdonnell Ranges.

Such was the state at the close of November, 1871, of the great undertaking in which the South Australian Government has embarked. A telegram received through the enterprise and energy of Reuter's Telegram Company (Limited) brings us further tidings to January 5, 1872, and states that "telegraphic communication with Port Darwin in connection with the Australian cable is now partially completed." This is rather vague and unsatisfactory, as the intelligence appears to have occupied some 20 days in finding its way from Melbourne to London, and the great line might also have been said to have been "partially completed" in November. On the other hand, it must be admitted that the intelligence vouchsafed by Reuter's Telegram Company makes mention of no fresh misfortune having been experienced by the South Australian Government in the prosecution of the work to which it stands committed; and, under these circumstances, it is, perhaps, fair to assume that Adelaide, Melbourne, Sydney, and Brisbane will be in almost instantaneous communication with London before the spring has run its course. The prosecution of a great Australian overland telegraph seems destined to exert a large influence for good upon the future of Australian colonization. Port Darwin can scarcely fail to become the nucleus of an important settlement in the north of Australia, and the construction and maintenance of the overland wire must also add greatly to our knowledge of the interior of the vast island continent which has hitherto been practically a sealed book. On the other hand, if it should be found a matter of great expense and difficulty to maintain a telegraph line in the interior of Australia, the South Australian Government may yet rue the day in which it embarked in so arduous an enterprise. Moreover, there is almost a certainty that a competitive route will be opened up by the Queensland Government, which will not have so very much to do to carry a wire to Port Darwin. Perhaps, also, in time a telegraphic wire may also be carried round the western coast of Australia, from Port Darwin to Perth, and thence to Adelaide. But however doubtful the prospect which may be before the South Australian Government of recouping itself for the expenditure which it has made in carrying a wire across the Australian interior, we can but admire the courage with which it entered upon the work, and the perseverance with which it is carrying it on to the end.

METALLIC BISMUTH, which is now largely used in the manufacture of pharmaceutical preparations, and in the composition of fusible metals, etc., has a high commercial value. The principal supply is derived from Bolivia.

THE PHOSPHATE SEWAGE PROCESS AT TOTTENHAM AND LEICESTER.

From "The Mechanics' Magazine."

The much controverted question as to the most practicable and efficacious method of dealing with town sewage, is in course of gradual solution, and may, it is to be hoped, ere long find a satisfactory settlement. The various committees that have been formed to inquire into the subject, and more especially the Reports of the Rivers Pollution Commissioners, have afforded reliable information of such an alarming character as to the impure condition of the rivers throughout the country, on account of the admission into them of every species of refuse, that the absolute necessity of adopting some system, in order, so far as possible, to remedy the evil, is now universally allowed. It is a matter that has deservedly gained the attention of scientific men, for the consideration of the subject involves many points upon which they alone are able to give a competent opinion. There can be no doubt, however, that the right place to dispose of the sewage of human dwellings is on the crop-producing lands; but how to get it there is apparently a somewhat perplexing problem. Within the past few years various schemes have been introduced to public notice, some of which aim at the purification of sewage before it is applied to the land, and these have been put upon their trial in different towns. The simple plan of irrigating the land with the sewage in its raw condition has been adopted in many places, where, up to the present time, it has been attended with successful results, so far as it is a means of disposing of the sewage; but the extent to which it can be carried must of necessity be limited, unless ample appliances be provided to convey the sewage to any required spot; and such an undertaking involves at the commencement a considerable outlay of capital for which an adequate return in the shape of interest cannot be confidently relied on, for experience has shown that, in general, sewage in the raw state has not yet attained a commercial value as a manure, at all proportionate to an estimate based on the extent of population. The difficulties to be encountered are numerous, no matter from what aspect the subject is viewed, and when any new scheme is brought forward, every one is anxious to examine its capabilities of dealing with the question at issue, since all are more or less interested in its satisfactory solution.

We propose, therefore, to describe a defecating system which has been patented by Professor David Forbes and Dr. A. P. Price, and to see with what success those difficulties have been met; the system about to be adopted by the local Board of Tottenham, to prevent pollution of the river Lea, and already adopted by the Town Council of Leicester, in substitution for the lime process, which has not been found efficacious in preventing the pollution of the river Soar. It has, therefore, substantial claims to a hearing.

The patentees affirm that their plan, which effects a precipitation of all solid matters, is superior to irrigation with the raw liquid, inasmuch as it purifies the sewage and produces a manure more available for agricultural purposes, and of an equal if not greater commercial value. The precipitating agent employed is a natural phosphate of alumina, which has been discovered in very large quantities in the West Indies—indeed, it is stated that an island called Alto Vela contains on a moderate computation, upwards of 9,000,000 tons thereof. Upon submitting this material to chemical analysis, Professor Forbes found it to consist of one equivalent of alumina, one of phosphoric acid, and five of water; and three samples of the phosphates showed the following percentage composition:

	No. 1.	No. 2.	No. 3.
Phosphoric acid	38.96	37.09	33.11
Alumina	27.06	26.08	24.57
Peroxide of Iron.....	2.68	2.76	2.07
Lime	1.94	2.09	1.08
Insoluble matter.....	6.70	9.10	17.00
Water, etc.	22.66	22.88	22.22
	100.00	100.00	100.00

The process of its application in the deodorization of foul sewage is very simple.

In the first instance it is reduced to a powder and then submitted to the action of sulphuric or hydrochloric acid, in the relative quantities of 10 parts of phosphate to 7 of acid, by which means it is decomposed and rendered soluble, when it has the appearance of a thick paste. The solution thus obtained—which is stated to be so powerful an antiseptic and disinfectant, that it effectually arrests further putrefaction, and renders the most fetid matter free from all offensive odor—may be used in this concentrated form, or it may be diluted with water (which is preferable) until it assumes a liquid state. Ii is now in a proper condition to be employed, and as the sewage is pumped into reservoirs or tanks, the desired quantity of the soluble phosphates is permitted to flow in and mix with it, an agitation being sustained during the process so as to insure a thorough admixture. When the tanks are full the sewage thus treated is allowed to remain tranquil and precipitation immediately commences. All the solid matter previously held in solution, which is now deodorized, gradually subsides and leaves a transparent effluent water, free from offensive smell or disagreeable taste, and differing but little from ordinary river water. But to remove any doubt that may exist as to the admissibility of this supernatant water into a stream, the patentees effect a still greater clarification by adding, during the operation, a small quantity of milk of lime, which causes a precipitation of the phosphates in solution—a result that is known by the "sewage acquiring a neutral or alkaline reaction." It is not pretended that this water is suitable for drinking, although Professor Forbes says it may be used for that purpose without repugnance; but it is alleged that it may be discharged into any river without the least apprehension of causing a nuisance, and in support of this assertion, Dr. Letheby states that "fishes can live in it, and, most important of all, it will remain for months in hot summer weather without showing any tendency to putrefy or emit a disagreeable odor; there is no doubt, therefore, that such water may be freely and safely discharged into a watercourse."

If it be determined, on the other hand, to utilize the sewage of a town by irrigation, or in those cases where land has already been prepared for that purpose, an equal advantage may be derived from the application of this process, so as to separate the solid matters from the liquid, and to remove their putrescence before they are distributed over the land; as it is not certain that any beneficial end is promoted by preserving an extremely offensive odor, which only pervades the surrounding atmosphere, or that slimy fetid sewage can best contribute to the growth of plants when applied in that condition; and, therefore, a precipitating plan, such as the phosphate process, capable of defecating the sewage without detracting from its agricultural value as a fertilizing agent, would be no disadvantage for irrigation; moreover, it has been stated on competent authority, that much benefit is gained, in utilizing sewage for this purpose, by first separating from it all, or a greater part, of its solid ingredients. The patentees particularly direct attention to this as a distinguishing feature of their system, and Professor Voelcker is of opinion that the effluent water is "more valuable bulk for bulk for irrigating purposes than the raw liquid," because, instead of losing any of its mineral fertilizing matters, it has become slightly richer in saline ammonia—a conclusion arrived at after a careful analysis of an imperial gallon of Tottenham sewage which gave the following results:

Constituents per Gallon.	Before Treatment.	After Treatment.
Soluble matters:	Grs.	Grs.
Organic matter and combined water (loss in drying the residue at 280° F.)	6.35	5.74
Carbonate of lime	10.80	6.44
Sulphate of lime	16.45	26.43
Carbonate of magnesia	7.18	7.58
Oxide of iron and alumina	.48	.17
Phosphoric acid	.58	.25
Chloride of Sodium	10.56	10.08
Alkaline carbonate (determined by difference)	4.05	5.75
Soluble silica	.70	1.01
Total solid matter in solution	57.15	63.45
Suspended matters:		
Organic matter	11.41	0.00
Containing nitrogen	.64	
Equal to ammonia	.76	
Mineral substances	5.11	0.00
Total suspended matter	16.52	0.00

The total organic and mineral matters, therefore, both in solution and in suspen-

sion, amounted to 73.67 grains in the raw sewage, while the effluent water contained 63.45 grains in solution, but no perceptible and weighable matters in suspension, which shows the extent of purification attained by the use of the phosphate of alumina.

A sample of London sewage, treated and analyzed by Dr. Letheby, gave similar results as to clarification, though the percentage of each constituent of the London sewage was considerably greater than that of Tottenham, which is explained by the fact of the former containing more solid substances than the latter. In those cases where the supernatant water is to be used for the purposes of irrigation it is not necessary to add the milk of lime, for the soluble phosphate which the lime precipitates, is a most important ingredient in assisting the growth of vegetation.

ILLUMINATING GAS.

From "The American Exchange and Review."

Among the requirements of civilized life, there are few which assert themselves with more emphasis than some convenient form of artificial light. Whether we consider the subject in its moral, social, or economical relations, and from whatever standpoint we may view the question, the fact remains, that light is one of the chief necessities of man, and in some form or other its artificial production has become more general and available in a direct ratio with the advance of knowledge and civilization. Among the applications of science to the arts, none have been more productive of useful results than those crude experiments in destructive distillation made by different investigators during the last century, which finally culminated in 1792 in the manufacture of illuminating gas. Whether regarded as a luxury or a necessity—for in both these aspects it presents its claims on our attention—its benefits have made themselves felt in all parts of the world ; and wherever culture and refinement have their abode we find this form of artificial light an indispensable requirement. "It has extended the available term of man's life by giving the hours of the night to his use. It has, by the social intercourse it encourages, polished his manners and refined his tastes, and, perhaps as much as anything else, has aided in his intellectual progress."* Its influence in reducing the tendency to crime in towns and cities has been recognized. So accustomed have we become to its use, and so constantly do we rely upon it, both in domestic economy and in the demands of industry, that we are prone to accept its benefits simply as a matter of course, and to frequently overlook the importance of the art which furnishes us with so efficient a service.

The history of illuminating gas has been often recounted. From the most authentic descriptions of its rise and progress, it is evident that its manufacture was suggested by the experiments made with natural gas issuing from the earth in close proximity to coal seams. In the writings of ancient authors, mention is made of perpetual fires which were burned on altars consecrated to the worship of mythological deities. Strabo and Plutarch refer to these mysterious fires ; while Herodotus, Vitruvius, and other early historians, allude to the bituminous wells of the island of Zante, whence issued streams of inflammable vapor, which were used to inspire the multitudes of superstitious worshippers with profound reverence for sacerdotal authority. In India and China these wells have been known from remote antiquity ; and it is said that in the latter country the gas thus naturally exuding from the ground has for a long time been conveyed in pipes made of bamboo, and used for boiling salt. Gas wells of this description abound in various parts of the world ; one of which, in England, was probably the means of suggesting the artificial production of gas, and its utilization as an illuminating agent. In this country several wells of more than ordinary interest have been discovered, yielding large volumes of gas of considerable illuminating power. Among them may be mentioned those in the town of Fredonia, New York, where two companies furnish light to a village of 3,000 inhabitants,

* Draper.

produced solely by burning the natural gas as it rises from the ground. At Bloomfield, in Ontario county, New York, there is a well, from which, according to the estimates of Prof. Henry Wurtz—one of the best authorities on the subject—the daily flow of gas is upwards sf 400,000 cubic feet. In Ohio, near the town of Gambier, remarkable wells of a similar character have been described by Prof. J. S. Newberry, where the gas has constantly flowed without apparent diminution of volume since 1866, and which, on being ignited from the orifice of a 2-in. pipe, produces a flame 20 ft. or more in length. Similar phenomena have likewise been observed in the petroleum region of Pennsylvania.

A stream of carburetted hydrogen gas issuing from a spring in the Wigan coal district of Lancashire, was observed in 1667 by Mr. Shirley, who communicated a description of it to the Royal Society of London. In his account of this phenomenon, it was rightly conceded that the "inflammable air" originated in the underlying coal seams. As the gas floating on the water of this spring could be ignited, it was generally believed that the liquid was inflammable, but Mr. Shirley demonstrated the error of this idea, and showed that it was merely the gas rising from the water, which burned. In 1726, Dr. Hales made a number of experiments on destructive distillation, using Newcastle caking coal, from which he obtained a gas which he burned for amusement. The quantity of this gas agreed very closely with the results of modern operations on a large scale. The experiments described by the Doctor in his work on "Vegetable Statics" must have been conducted in a very small way, as he mentions having used but 153 grains of coal, from which he obtained 180 cubic in. of gas. This yield is equivalent to about 8,500 cubic ft. per ton. But prior to the publication of Dr. Hales' book, the Rev. John Clayton had amused himself with experiments on the distillation of coal, which he did not publish, however, until 1739. In a letter written before this date to Hon. Robert Boyle, he gives a very quaint account of his operations, wherein he states that having introduced a quantity of coal into a retort, and placed it over a fire, he continues: "At first there came over only phlegm, afterwards a black oil, and then likewise a spirit which I could no ways condense; but it forced my lute or broke my glasses. Once when it had forced my lute, coming close thereto in order to try and repair it, I observed that the spirit which issued out, caught fire at the flame of the candle and continued burning with violence, as it issued out in a stream, which I blew out and lighted again alternately for several times. I then had a mind to try if I could save any of this spirit; in order to which, I took a turbinated receiver, and putting a candle to the pipe of the receiver whilst the spirit arose, I observed that it catched flame, and continued burning at the end of the pipe, though you could not discern what fed the flame. I then blew it out and lighted it again several times; after which I fixed a bladder, squeezed and void of air, to the pipe of the receiver. The oil and phlegm descended into the receiver, but the spirit, still ascending, blew up the bladder. I then filled a good many bladders therewith, and might have filled an inconceivable number more; for the spirit continued to rise for several hours and filled the bladders almost as fast as a man could have blown them with his mouth, and yet the quantity of coal I distilled was inconsiderable. I kept this spirit in bladders a considerable time, and endeavored several ways to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders, and pricking a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising because no one could discern any difference in the appearance between these bladders and those which are filled with common air."

In 1733 a communication was made to the Royal Society by Sir James Lowther, on the subject of "inflammable air" which escaped from a coal mine near Whitehaven, which readily ignited, and was with difficulty extinguished. This gas was also collected in bladders, and burned in the presence of members of the Society. It attracted much attention, and seems to have produced a lasting impression, for as late as 1765 a proposal was made to convey the gas in pipes to light the town;

but the idea was regarded as chimerical, and was soon abandoned. The experiments of Mr. Clayton, although for a time apparently forgotten, seem to have supplied the germ from which subsequent developments sprung, for they partook more of the character of philosophical investigations than any of the hap-hazard essays which preceded them.

In alluding to the history of this important branch of industry we cannot pass over the observation of Dr. Watson, that coal gas is unaltered by being passed through tubes immersed in water; or, in other words, that the condensation of some of its constituents does not impair its illuminating properties. This fact is noticed in the "Chemical Essays" of this gentleman, published in 1767. Other experiments of this nature continued to be performed by various persons, but with little or no practical results. In 1787 Lord Dundonald, a Scottish nobleman, secured a patent for making coal tar—or, more properly speaking, coal oil, for this was the substance he desired to produce. In condensing this product, the gaseous body eliminated by the distillation of coal was collected for amusement and curiosity; and no other purpose than that of the entertainment of his friends seemed to inspire his exertions. These investigations, however, were not without their fruit. A countryman of his Lordship, by the name of Murdoch, then living at Redruth, in Cornwall, who had read of the experiments above described, was led to investigate the nature of the products of distillation, and extended his researches to the volatile bodies obtained from peat, coal, wood, and other combustibles. These investigations were pursued with some degree of system, and it was ascertained that by properly regulating the processes of carbonization and condensation, a uniform product of high illuminating power might be obtained. The practical mind of Murdoch soon appropriated the idea, that by constructing receptacles for the gas, and conveying it through pipes, it might be manufactured and utilized on a large scale. He lighted his own house in this manner, conveying the gas in pipes about 70 ft. from his miniature gas works, and likewise constructed a portable gas lantern which he carried with him at night, much to the discomfiture of the superstitious peasantry of his neighborhood, who strongly suspected him of witchcraft. In 1798 Murdoch erected gas works at Messrs. Boulton & Watt's Soho foundry, and having entered into the employment of that firm, he personally superintended the operation, and gradually perfected the details of the manufacture. That gas illumination, as illustrated by its employment at this factory, was a success, cannot be doubted; and yet several years elapsed before it was generally adopted. In 1802, at the illumination in honor of the peace of Amiens, the superiority of the display produced by the Soho foundry was so marked that general attention was attracted to the new method of illumination, and its use gradually extended. A number of large cotton mills were lighted by gas about the year 1805. The Lyceum theatre of London was the first place of amusement which employed it, and in a short time, its advantages having become better appreciated, its use became more general. But notwithstanding the fact that these advantages obtained a wider recognition, some opposition was manifested to its introduction. Grave predictions of danger were uttered, and no little ridicule was cast upon the project. When Napoleon was informed of the subject, he remarked: "*C'est une grande folie.*" Sir Walter Scott was no less incredulous, and said that he feared London would be on fire by it, from Hackney gate to Tyburn; while Lord Brougham declared that "the idea was worthy of the philosopher who proposed to extract sunbeams from cucumbers"—a remark, by the way, which, though uttered in a spirit of irony, in the light of modern scientific opinions contains elements of sober reality. Even Sir Humphrey Davy considered the idea of utilizing gas so ridiculous, that he contemptuously asked "if it were intended to take the dome of St. Paul's for a gasometer."

As soon as gaslight became firmly established in England, its merits claimed recognition on this side of the Atlantic, and in 1816 the first American gaslight company was chartered to light the city of Baltimore. Six years later, in 1822, Boston adopted the new method of illumination; while the old New York Gaslight Company, which lights the city from Grand street to the Battery, was chartered in 1823. Brooklyn and Bristol, R.

I., were lighted in 1825. In 1830 the Manhattan Gaslight Company of New York, now the largest and wealthiest in America and fourth in size in the world, was chartered. The district of this corporation extends from Grand street to Thirty-fourth, and from river to river. Other cities pronounced in favor of the new light as follows: New Orleans in 1835, Philadelphia and Pittsburgh in 1836, Louisville in 1838, Cincinnati in 1841, Kensington (Philadelphia) in 1844, Albany in 1845. From this date gas works multiplied with rapidity, and as the superiority of the new light became evident, cities and towns in all parts of the country were soon supplied with it.

The Baltimore gas works were originally constructed to make gas from coal tar, but this plan proved a total failure, as might have been predicted. After this unsuccessful experiment, the works were reconstructed by an English engineer, but this change not proving satisfactory, they were again remodelled, and gas was made from bituminous coal. In Boston a mixture of coal and rosin was used, while in the two New York companies rosin alone was employed. All of these works were deemed more or less defective, and when, in January, 1833, the question of erecting gas works in Philadelphia was brought before the councils, a committee was appointed to consider the question and to make a report. In January, 1834, it was resolved to send an engineer to Europe for the purpose of investigating the best gas works there in operation, and to obtain such information as might be useful in erecting works in the city. The late Samuel V. Merrick was selected for this mission, and in furtherance of his instructions he sailed in March, returning in December of the same year. Notwithstanding a violent opposition to the project, gas works were erected by Mr. Merrick, and on the 10th of February, 1836, Philadelphia was first lighted with gas.

All substances of an organic nature when exposed to a high temperature in close vessels, undergo a remarkable transformation. If the experiment be performed in a retort, and that portion which is volatilized by the heat be cooled and collected, it will be found that the original substance has been split up into three distinct bodies, viz., the solid coke which remains in the retort, tarry matters (including water), which condense to a liquid, and permament gas. A still further examination of these products would disclose the fact, that, although they present a homogeneous appearance, they are really mere mixtures of various bodies, which are capable of minute subdivision; and that the liquid tarry matter contains substances which, when isolated, assume a solid form. Complex as these bodies, they are essentially composed of but two of the elements—carbon and hydrogen—although they include notable quantities of other elements, which, however, are regarded as impurities, and which, in the details of gas making, are eliminated as completely as possible. Among these objectionable substances are oxygen, nitrogen, and sulphur, which exist in various combinations, and unless removed from the finished product, greatly impair its quality.

A number of raw materials are available in the manufacture of illuminating gas. Almost every combustible body, when subjected to destructive distillation, yields gaseous products suitable for generating light. Coal, wood, peat, oil, rosin, fats, bones, and a variety of other substances, have been used; but, generally speaking, bituminous coal may be said to be, *par excellence*, the natural source of gas; and as such we find it almost universally employed, although the other substances above mentioned are sometimes used when local considerations render their adoption desirable.

Of the coals which are included in the generic term bituminous, there are many varieties, some of which are admirably adapted to the manufacture of gas, while others are of too inferior qaality to justify their employment. As a general rule, it may be said that the larger the quantity of volatile matter yielded by a coal, the better it is fitted for the gas works; and yet this rule is not without its important exceptions. The English cannels, which are regarded as the best gas coals, vary in their content of volatile constituents, ranging from twenty-seven per cent., in the Washington, to sixty-nine per cent., in the Boghead, with a long list of other coals of the same variety, intermediate between these two extremes. In Great Britain cannel coal is sometimes used

alone as a source of gas, but it is generally distilled in conjunction with ordinary bituminous or caking coals, for the purpose of enriching the gases produced from the latter. This latter variety of coal is the main dependence of the gas works. In this country it is used almost exclusively; the few exceptions being in large cities near the seaboard, where certain proportions of English cannel are mixed with it. The advantages of ordinary bituminous coal consist in the fact that it is cheaper than cannel, and while it yields a gas somewhat inferior in illuminating power, it produces a coke of great excellence, which cannel does not; and as this material is one of the most important residual products of gas works, its quantity and quality are subjects of considerable moment. Moreover, the quantity of sulphur contained in ordinary bituminous coal is generally less than that in cannel, which is a decided advantage.

Most persons are familiar with the appearance of gas works. Located generally on the outskirts of towns, in places convenient either to water or railway communication, their numerous buildings, gas holders, etc., form conspicuous objects. In the manufacture of this illuminating agent, coal in charges of from 120 to 160 lbs. is quickly thrown into retorts, which are maintained at a bright red heat, from which the gases and vapors are conveyed away by means of upright iron pipes projecting from the front end of the retorts, and technically known as standpipes. After being charged, the retorts are quickly closed, the lids being luted, and forced against the mouthpiece either by means of a screw or a lever, so that they make a gas-tight joint. An improvement in retort lids has been lately introduced in the Dublin gas works, where the lids are hung on hinges and have machine-turned edges, which are brought in contact with the mouthpiece of the retort, which is also turned true, and the necessity for luting is obviated. The lids are gas-tight, and are held in position by means of a lever. A single charge remains in the retorts usualy about six hours, at the end of which time the lid is removed, and the gas remaining in the retort is ignited, so that it my quietly burn away while the coke is withdrawn. This is accomplished in a few moments, when a fresh charge is thrown in, and the evolution of gas goes on almost without intermission.

From the standpipe the gas passes through the dip-pipe into the hydraulic main, which is a large tube or trunk, usually made of cast iron, extending along the whole length of the retort house. The dip-pipes terminate in this main, their extremities extending 3 or 4 in. below the level of the liquid in the main, thus preventing the return of gas which has passed the end of the pipe. When the gas works are first put into operation, the hydraulic main is half filled with water, but this fluid is soon displaced by the heavier tar which condenses from the crude gas, so that in a short time the liquid contents of the main consist almost wholly of tar. Through this liquid the gas bubbles as is is eliminated from the retorts, depositing additions to the fluid contents of the main in the shape of tar and ammonia water, which my means of suitable pipes regulating their level, flow off to their appropriate receptacles.

From the hydraulic main, the gas, somewhat cooled, but still containing many condensable products, passes on to the condensers; but as in many works different intermediate methods are employed to cool and wash the gas, a brief reference to the various steps resorted to in this stage of the process may be advisable; although it must be premised that in many small gas works some of these processes are omitted altogether. In some instances the gas is caused to pass through a depth of several inches of water, which removes a portion of the ammoniacal products, and causes a further deposition of tar, while sometimes the gas is scrubbed by being compelled to pass through layers of moistened coke, and at others, subjected to streams of water conveyed through rose-jets. Many engineers, however, still oppose the use of the scrubber, or any direct contact of the gas with water, the reason alleged being that this treatment reduces its illuminating power. The condenser proper, in which the final cooling takes place, consists of a series of upright iron pipes, sometimes exteriorly cooled by water and sometimes by air. By these methods of cooling, the gas which leaves the hydraulic main in a heated condition is discharged into the purifiers at a temperature but little higher than that

of the atmosphere—sometimes, indeed, where water condensation has been used, below it.

The earliest method of purification, known as the wet lime process, was introduced by Mr. Clegg, an eminent English engineer, whose practical mind soon became convinced of the necessity of removing the noxious products of the combustion of gas, by the influence of which much damage was done to pictures, gilding, and other ornamental objects. By this process, ordinary caustic lime was mingled with water in the proportion of one bushel to forty-eight gallons, and through this mixture the gas was compelled to bubble. As far as efficacy was concerned, this method of purification was satisfactory; but in the economy of manufacturing operations, it was found that the pressure upon the retorts, which was induced by the gas being compelled to pass through several inches of liquid, caused a decomposition of the richer hydrocarbons, and a corresponding deposition of carbon in the retorts, as well as creating a variable amount of leakage from the latter. These objections resting on valid grounds, endeavors were made to obviate them, which was accomplished by Berard, who introduced purification by means of dry lime. The apparatus required by this modification consists of a series of receptacles, generally square in form, in which are placed a number of trays, containing moist slaked lime, spread in layers of 2 or 3 in. in thickness. Through this substance the gas is passed, and when it emerges, after having traversed successive layers, it is finally discharged into the gas-holders, whence it is distributed to consumers.

From the foregoing brief, and, in the absence of illustrations, necessarily imperfect description of the manufacture of gas, it will be seen that the process is comparatively a simple one, and yet there are questions continually presenting themselves in the routine of operations, which demand no little scientific and practical knowledge; hence we generally find gas works placed under the supervision of persons of more than ordinary intelligence. In our large cities, gas engineers are generally selected on account of their scientific attainments, which include not only a reasonable acquaintance with the principles of chemistry, but more especially a knowledge of the physical properties of fluids, practical experience in the construction of buildings, furnaces, and the like together with such other branches of information as are constantly required in the business. In England, and in all countries where large gas works abound, the profession of gas engineering includes, among its votaries, men of the highest culture and education; and the literature of this branch of technology has been enriched by contributions which are indispensable in every well-appointed scientific library.

Although more than 70 years have elapsed since coal gas was adopted as a source of artificial light, yet the principal features of its manufacture maintain a remarkable conservatism ; and, with few exceptions, the changes which have taken place in the interval have partaken more of the nature of perfecting the apparatus employed than any real improvement in the process itself. This process, conspicuous alike for its simplicity and for the fact of its being the "realization of profound scientific research," is essentially the method introduced by Murdoch and perfected by Clegg and Berard ; and although the labors of these eminent engineers have been somewhat supplemented by the experience of their successors, yet no radical improvement has been effected. The three steps into which the manufacture may be divided—carbonization, condensation, and purification—are virtually, in theory and practice, the same operations as were introduced by these pioneers of the profession. Perhaps one exception may be made to this assertion, in the substitution of oxide of iron for lime in the purifiers. But when we take into consideration the fact that this change was made, not for the purpose of improving the product, but chiefly, if not entirely, to obviate the foul odors arising from the spent lime, it can hardly be classed with inventions strictly intended to perfect the process of making gas. Purification by means of oxide of iron was patented in London in 1840, and since that time a number of modifications of the process have been perfected; but their adoption has been far from general. In London and a few other cities, gas companies have been compelled, for sanitary reasons, to resort to some form of oxide of iron purification. In New York the Board of

Health recently insisted on the substitution of this process for lime purification, by the companies embraced within the metropolitan district.

A brief allusion to the impurities contained in crude gas, and the means employed for their removal, may not be uninteresting, and in order to arrive at a correct comprehension of this process, it will be necessary to revert to the products of the distillation of coal. As we have before remarked, these products exist as solids, liquids, and gases. Dismissing the familiar subject of coke from our attention, the other results of the carbonization may be classified as follows: First, those which are permanently gaseous at the ordinary temperature of the atmosphere; second, those which, though gaseous when subjected to the temperature of the retort, by perfect condensation assume a liquid form; and third, the solid constituents. Among the products of the first class are olefiant gas, acetylene, hydrogen, marsh gas, carbonic acid, carbonic oxide, sulphuretted hydrogen, etc. In the second class are included benzole, naphtha, aniline, carbolic acid, bisulphide of carbon, creosote, toluole, etc., while among the constituents of the third class are various salts of ammonia, naphthaline, paranaphthaline, paraffine, etc. The bodies constituting the last two classes are embraced in the tar and ammonia water which flow from the hydraulic main, although certain proportions of them sometimes escape condensation, and pass on with the permanently gaseous products. The condensation of these bodies is a matter of some importance, especially in cold weather; for if too large a proportion of them are distributed with the gas, they are apt to condense in the pipes, sometimes to such an extent as to stop the flow of gas.

Of the gaseous bodies enumerated in the first class of products, the removal of the carbonic acid and sulphuretted hydrogen demands great care. The former of these compounds greatly impairs the illuminating power of gas, while the latter by its combustion eliminates sulphurous acid, which exerts a deleterious influence on gilding, pictures, and other decorations. These substances are readily absorbed by lime, and if the process of purification be properly conducted, there is no reason why more than mere traces of them should be found in the gas. Another compound of sulphur which exists among the liquid products, but which is so volatile that it freely passes the condensers, is much more difficult to remove. This is the bisulphide of carbon, which is the source of nearly all the sulphur found in the analysis of gas.

The permanently gaseous products of the carbonization of coal, those which form the object of manufacture, are marsh gas, or light carburetted hydrogen, with some olefiant gas, or ethylene, and traces of acetylene. When ordinary bituminous coal is alone used in the retorts, the product contains but a small proportion of the two latter ingredients, being chiefly composed of marsh gas, which possesses a lower degree of illuminating power, as well as a lower specific gravity. As before remarked, cannel coal—which yields a larger proportion of olefiant gas, having a much higher illuminating power—is sometimes used with bituminous coal in varying proportions. In the Manhattan gas works of New York a mixture of equal weights of cannel and caking coal is used in the winter, while the summer proportions are one-third cannel to two-thirds of caking. The reason of this variation is because in winter the luminous gases and vapors suffer from condensation caused by cold weather, whereby the quality of the product would be impaired unless restored by a larger proportion of richer constituents.

The residual products of gas works form important objects of attention, and upon their proper treatment depends much of the prosperity of the business. Coke generally commands a ready sale, and although a considerable proportion of this product is used to heat the retorts, a large surplus is made. Coal tar is another important residue, the uses of which are extending in every direction. Within the past few years the investigation of the various products of this complex substance has opened up new fields of study, and rapidly advanced the scope of organic chemistry. It has been but a short time since the discovery of the beautiful aniline series of colors, which now form such important objects of manufacture, and from which tints are derived rivalling the richest colors produced from other sources. In addition to these products, pitch, creosote, carbolic acid, naphtha,

and benzole are manufactured from the tar, together with a number of less important hydro-carbons.

The ammonia liquor which condenses in the hydraulic main along with the tar, and which floats upon the surface of the latter, is the source of all the salts of ammonia of commerce. It is converted into either sulphate of ammonia or sal ammoniac, by the addition of sulphuric or muriatic acid, as either salt may be required, and evaporated to crystallization; but this method is slow and expensive, on account of the great amount of evaporation necessary. In the manufacture of sulphate of ammonia, a much better way is to transfer the liquor into a boiler, and to add milk or lime, and then to blow steam into it. The ammonia is rapidly liberated in a gaseous form, and conveyed through pipes into a lead-lined tank containing sulphuric acid of 60 degrees. In a short time crystals of the sulphate are formed, which are raked out on a lead-covered inclined shelf to drain, the drippings being allowed to run back into the tank. In Europe, the ammonia liquor is utilized in nearly all gas works, but in this country, with the exception of a few works in large cities, it is allowed to waste. Ordinary English bituminous coals yield about thirty pounds of sulphate of ammonia per ton.

The refuse lime which has fulfilled its office in purifying gas, is generally disposed of at cheap rates for fertilizing purposes. In some localities it is used to manufacture hyposulphite of lime, which, by treatment with carbonate of soda, is converted into hyposulphite of soda, but its employment in this way is very limited.

Although, as we have remarked, the process of manufacturing illuminating gas is eminently conservative, yet patents without number have been taken out in most civilized countries, for the purpose of effecting supposed improvements. So far as inventions essentially relating to the chemical process itself are concerned, it is safe to say that a vast proportion have been utterly worthless. One of the most prolific sources of these innovations has become manifest in the numerous delusions in which water-gas has loomed up as a veritable *ignis fatuus;* holding forth its alluring promises, ever doomed to certain disappointment. To give a more retrospective glance at these chimerical schemes would fill a volume of no moderate dimensions; and we must be content with simply a brief allusion to them and to the principles which underlie the attempts to utilize water in this branch of technology.

It is a fact well known to chemists, that certain metals possess the property of decomposing water at ordinary temperatures, in which reaction the oxygen of the water combines with the metal, forming an oxide, while the hydrogen is liberated in a gaseous state. The metals sodium and potassium afford illustrations of this fact. Other metals, among which are iron and zinc, decompose water or steam at a red heat, with a similar reaction; while incandescent coke or charcoal possess the same property, but in this instance the oxygen of the water combines with the carbon, forming a mixture of carbonic oxide and carbonic acid and hydrogen. Water may be likewise decomposed into its gaseous elements by electricity. Upon the application of one or the other of these methods of obtaining hydrogen have rested the claims of water-gas inventors. In the long list of patents which have been obtained in this special department of technology, the first of which we have any record was that of Vere and Crane, of England, bearing date in 1823. Their process claimed the introduction of water or steam into a gas retort while in operation. A short time subsequent to their alleged invention, Ibbotson patented substantially the same process. In 1830, Pinkus and Collier followed with a patent very similar in its provisions, and in the same year Donovan succeeded with a process in which the gases caused by the decomposition of steam by red-hot coke were impregnated with the vapors of turpentine, naphtha, and other hydro-carbons. In 1834, Seligue, Jobard, and Mollerat, three Frenchmen, patented processes very similar to each other, and almost identical in principle with Donovan's. In the following year Gilbert Sanders took out a patent in England, using the old familiar design of steam and red-hot coke. In 1847, White's process of decomposing steam by red-hot iron was brought out; and two years later Gillard patented in France a water-gas process, in which he obtained hydrogen by decomposing water by the magneto-electric machine, subsequently rendering the gas

luminous by passing it through volatile hydro-carbons. In 1850, Paine attempted to astonish the world by his process, which was almost identical with that of Gillard, but which was claimed by its inventor to possess the remarkable power of converting water "entirely into hydrogen, or entirely into oxygen, at will." The wonderful claims made in behalf of this "invention," and the extravagant assertions made by its patentee, are fresh within the memory of many of our readers. Since this time water-gas patents have been issued with a rapidity which almost exceeds belief; and numerous self-styled inventors have exhibited considerable ingenuity, not in the processes devised, but in so concealing old, exploded, and worthless methods behind a mass of cunningly arranged words, as to deceive the officials of the Patent Office into the belief that patentable novelty could really be found in their devices. Among American patents of this class which have sprung up amid a grand flourish of trumpets, and which have been "tried, weighed in the balance, and found wanting," may be mentioned those of Sanders, Gwynne, Elmer, Thompson, and a host of others.

An erroneous idea which has prevailed to a great extent—that by admitting nascent hydrogen into a retort where hydrocarbon vapors are being evolved would result in forming rich permanent gases—has formed the basis of the greater part of these water-gas patents. Because coal tar consists of hydro-carbons in which carbon exists in large proportions, it has been assumed that a union of these tar vapors with hydrogen might be brought about, and the important object of economy largely subserved. In chase of this phantom large amounts of money have been squandered, and although many of these innovations have been subjected to thoroughly impartial tests, and every facility extended to ascertain the truth, they have all of them been found worthless and consigned to a merited obscurity. As one of our most experienced gas chemists justly remarks: "In gas coal nature has placed the constituents necessary to yield all the advantages which the application of water-gas may possess. Water is one of the products of carbonization, but that fact has probably been overlooked by some of our engineers, because it is called in hand-books ammoniacal liquor. Why should that water which is present in excess, and which is produced from the very coal itself in the form of steam, or even superheated steam if you please, in the presence of tar vapors, and finely divided carbon, and which is in the nascent state if ever anything was so—why should it not, without any additional expense, be decomposed in the same manner as when you pass it into a separate retort, over red-hot charcoal, or coke, or anthracite coal, or iron turnings, or even zinc?"*

In Great Britain and Ireland, gas works are much more numerous than in this country. Almost every small village of a thousand inhabitants is lighted with gas. In 1860 the total number of companies in the United Kingdom was 1,015, distributed as follows: England and Wales 810, Scotland 141, Ireland 64. The aggregate capital at that time invested in the business was very nearly $100,000,000. The average price charged to private consumers was about $1.80 per 1,000 cubic ft., with discounts made to large customers ranging from 5 to 30 per cent. Compared with the charges made by our American gas companies, this rate seems very low; but it must be remembered that labor, and consequently coal, iron, and all other essentials are far cheaper than on this side of the Atlantic.

In the whole territory of the United States there are not 500 gas-light companies. The last accurate tables we have been enabled to obtain were compiled from official sources in 1863, and the number then returned was 433. At that time the price charged to consumers per 1,000 cubic ft. ranged from $1.50 at Pittsburg, to $12.50 at Marysville, California. In this country, as in England, gas companies are usually private corporations, the exceptions to this rule being Philadelphia, Alexandria, Richmond, Va., and Frankfort, Ky., where the gas works are owned and operated by municipal authorities, or by trustees to whom their management is delegated. In considering the question whether it is more desirable for the consumer to be dependent on a municipal or a private corporation, opinions are divided; but experience has proved that there is little if any difference in the practical results; and that if

* Dr. John Torrey.

there is any difference, it is not in favor of municipal management. In all cases the same rules of selling gas are observed; the same meters are used, and the same apparently arbitrary methods of treating delinquent consumers, or their successors, are followed.

Gas companies are always made the target at which are aimed the shafts of indignant consumers; and no matter whether these are served by city works or by private corporations, the result is always the same. But whatever plan of dispensing illuminating gas may be pursued, the advantages of this over every other form of artificial illumination must be conceded. Its cleanliness, safety and economy are universally recognized; and were we compelled to undergo the deprivation of some of the essential comforts to which we have become accustomed, one of the last necessaries we would voluntarily relinquish would be illuminating gas.

CHEMICAL PHENOMENA OF IRON SMELTING.—SOME OF THE CONDITIONS WHICH APPARENTLY AFFECT THE QUALITY OF THE IRON.

By Mr. I. LOWTHIAN BELL.

From "The Journal of the Iron and Steel Institute."

Unlike other metallurgical operations for obtaining a metal from its ores, the iron blast furnace delivers its product of different qualities, well known as foundry and forge iron. The former embraces the dark gray, in crystals, designated Nos. 1, 2, 3, and Foundry No. 4, the color becoming lighter and the crystals smaller as we descend in the scale. Forge iron commences where the foundry ceases, and includes forge No. 4, mottled and white. As is well known, however, to manufacturers, very gray iron is frequently used in the forge, and sometimes, for particular purposes, the forge qualities are required in the foundry. As a rule, a furnace is especially devoted at certain times to the production of a particular quality of metal, this being done by using a smaller quantity of ore, on a given weight of fuel, when foundry iron is sought for, than when forge iron is the object in view.

It may be inferred from this mode of treatment that, for the higher numbers, beginning at No. 1, a more intense temperature is necessary than for the lower, and in consequence of this greater heat, it is not unlikely there may also be some change in the chemical constitution of the product. As regards the first of these suppositions, there can be no doubt that a given quantity of fuel, having a reduced amount of duty imposed upon it, must perform that duty at a correspondingly increased temperature, and this view is confirmed by actual observation. With respect to the second, an opinion is prevalent that the "richer" the iron, as it is called, *i. e.* the nearer it approaches to No. 1, the more carbon has it taken up, and the greater is the proportion of this carbon in the uncombined or graphitic state.

I propose to examine these two questions in the present section.

I believe it will be generally admitted, that if a furnace were working steadily with Cleveland stone, on rich foundry iron, say, half No. 1 and half No. 3, equal to average of No. 2, an addition of 1½ cwt. of mine to the burden carried by 1 ton of coke, would suffice to lower the quality to an average of No. 4, or about two numbers below its former mark. This addition is equivalent to reducing the consumption of coke about .8 cwt. per ton of iron. Assuming that in each case all the CO_2 generated by the action of the ore on the CO, escapes as such, this weight, .8 cwt. of fuel, burnt with hot blast, will all escape at CO, and represent about 2,400 units. If this be correct, then each number, as we ascend in the scale, will require for its production, probably, about 1,200 units, or something like .4 cwt. more coke than the number under it.

I was very anxious to determine, by actual experiment, the difference of temperature in a furnace while running different qualities of iron, and this I endeavored to do by ascertaining the heat of the slag.

Several attempts were made to get this by introducing into an ordinary calori-

meter, containing ice, a given weight of slag, as it ran from the furnace, and judging of the temperature by the quantity of ice which was melted. The numbers obtained were as follows :—

				Grammes.
Exp. 632.	Ice melted per gramme of slag			7.01
" 633.	do.	do.	do.	6.88
" 634.	do.	do.	do.	8.09
" 635.	do.	do.	do.	7.51
" 636.	do.	do.	do.	6.70
Average				7.238

The variation is from 6.70×79 calories $= .529$ calories.
to 8.09×79 " $= .639$ "

Average 584

The want of uniformity in these experiments with the ice calorimeter, arising chiefly from a varying quantity of ice melting in the external chamber, induced me to try a different plan. A copper vessel, having a capacity of about 12 litres, was surrounded by an outer one, forming a hermetically closed air space. The whole was enclosed in a wooden case, to lessen the loss from radiation, etc. Ten litres of water of a known temperature were poured into the inner vessel, and kept in readiness close to the current of slag, the temperature of which had to be ascertained. A cast-iron crucible, of a tapering form, capable of holding about 200 grammes was placed in one of earthenware to prevent loss of heat. A quantity of the slag was poured rapidly into the iron crucible, and a lid, luted with tempered clay, was pressed into it so as to exclude the water when the whole was immersed in the ten litres of water. As five minutes elapsed before the water ceased rising in temperature, experiments were made to determine the loss during this delay, which was ascertained to amount to 4.04 per cent.

The highest number obtained in this way was 504 calories per unit of slag, which is about 9 per cent. below that of M. Vathaire, possibly owing to loss of heat in transferring the slag to the crucible and the crucible to the water. Occasionally, the number was 40 calories below this, and this often, when the experiment was the most expeditiously performed, which induces me to think that, in the hearth of the furnace itself, there are irregularities of temperature, occasioned probably by changes in the quantity of fuel compared with the ore, arriving at the tuyeres. At any rate, the fluctuations were too great to render it easy to determine the difference in temperature of a furnace making different qualities of iron.

Exp. 637. At one of the Clarence furnaces, which had been working for some time steadily on No. 4 iron, the temperature of the blast was purposely lowered, so that something like 800 calories less per ton of iron entered the furnace. The iron fell to mottled and some white iron while the change was continued, but returned to No. 4, soon after raising the temperature of the air to its former pitch.

Being desirous of knowing whether the temperature of the escaping gases afforded any indication of what was going on in the hearth, two of the Clarence furnaces (capacity 25,500 cubic ft.), and both working on the same burden of minerals, were experimented upon for periods of six to seven hours, upon different days. The temperatures were taken every ten minutes, by means of the electric pyrometer.

No. 4 furnace, making

No. 2. iron.	No. 3 iron.	No. 4 iron.
Temp. of gases.	Temp. of gases.	Temp. of gases.
345° C. (653 F.)	335° C. (635 F.)	343° C. (650 F.)
	334° C. (633 F.)	

No. 5 furnace, making

No. 3 iron.	No. 4 iron.
Temp. of gases.	Temp. of gases.
363° C. (685 F.)	347° C. (656 F.)
342° C. (648 F.)	
376° C (709 F.)	

From these figures which give 345 deg. C. (653 deg. Fahr.) for No. 2 iron, an average of 350 deg. C. (630 deg. Fahr.) for No. 3, and 345 deg. C. (653 deg. Fahr.) for No. 4, it may be concluded that any excess of heat evolved during the production of the higher number was absorbed and carried away by the iron and slag, because there is practically no difference in the temperature of the escaping gases. In all probability, also, there would be somewhat less heat generated in making the lower quality of iron, most likely due to alterations in the quality of the coke itself.

Repeated allusion has been made, in previous portions of this work, to the complex nature of the action of the blast furnace, and how readily its progress is interfered with by irregularities in the quality of the materials, by want of care in charging, by alterations in the temperature of the blast, or even by changes in

the atmosphere, and that these irregularities might amount to fully 5 per cent. on the fuel consumed, or even more. Nothing, therefore, is more easy to comprehend, than that a furnace making any given quality of iron, should slip down a number, or the reverse, when it is remembered that about one-fourth of this 5 per cent. suffices to cause the change.

As a rule, I have assumed, in my estimates of the standard of heat appropriation, that No. 3 iron was being produced; this quality, or from that to No. 3.5, being the usual average run from the furnaces in the vicinity of Middlesbrough.

I am aware my figures have been objected to by some of my fellow iron-masters, whose word is beyond dispute, and for whose experience and knowledge I entertain the highest respect. I believe these discrepancies may often, if not always, arise from a difference of the circumstances under which the furnaces are worked. Thus, supposing a manufacturer required a large quantity of foundry iron, say Nos. 1 and 3, it would be necessary for him to work with such a burden as would insure a margin of heat which would cover all the contingencies I have mentioned, and even then he might receive as much No. 4 as would reduce the average to No. 3. On the other hand, a second maker holds orders chiefly for No. 4, and his furnaces are burdened accordingly, but owing to a combination of favorable conditions, he produces, over some days, nothing but No. 3 iron, which he, of course, will do with a consumption of fuel which will contrast very favorably with that of his neighbor, who is bound to furnish his customers with richer iron in the face of adverse conditions.

Before concluding this section, further proof will be adduced of the influence of temperature in determining the quality of iron from the blast furnace; but before giving this, it will be convenient to consider whether the application of this additional heat changes the chemical composition of the metal when it changes its quality in point of richness.

To determine this, a great number of analyses by the processes already described were made of iron of all numbers, of which the following are examples:

Quality of the Iron.	Exp. 638. Clarence. No. 1.	Exp 639. Clarence No. 1·	Exp 640. Clarence No. 1·
Fe, by difference	92 913	72 288	92.601
P	1.502	1 174	1.538
S	.071	.055	.063
Si...	1.683	1 585	1.634
C uncombined	2 282	2.722	2 502
C combined	.789	1.149	969
Slag.....	.760	1 027	893
	100.000	100.000	100.000
Total carbon....	3 071	3.871	3.471

Quality of the iron.	Exp 641 Clarence. No. 3.	Exp. 642 Clarence No. 4.	Exp. 643. Clarence. No. 4.
Fe, by difference	92.550	93 003	92.422
P	1.570	1.480	1 676
S	.108	.072	.023
Si.....	1 372	1.531	1.353
C uncombined	2.758	2.504	2 686
C combined	.722	.790	.920
Slag.....	.920	.620	.920
	100.000	100.000	100 000
Total carbon....	3.480	3.294	3.606

Quality of the iron.	Exp. 644. Clarence White.	Exp. 645. Clarence White.	Exp. 646. Wear White.
Fe, by difference ...	93.181	94.104	90 908
P	1.318	1.134	1.554
S.....	.199	.016	.209
Si.....	.640	.900	2.025
C uncombined	2.209	2 472	2.539
C combined	.993	1 014	.745
Slag.....	1.460	360	2.020
	100 000	100.000	100.000
Total carbon....	3.202	3.486	3.284

If these figures are to be relied on, it cannot be pretended that carbon, either by greater quantity, or by any peculiarity of form, is the cause of the difference between white, and other kinds of iron; for there is to be found among the above, one case of No. 1 pig (Exp. 638) having 3.071 per cent., of which 2.282 is graphitic, against 3.284 per cent., of which 2.539 is graphitic (Exp. 646), in a sample of white iron. If, again, any other substance, found in the above specimens, is examined, it will be observed that there is no feature connected with its presence, to which we can ascribe the variations in quality.

The inference I would draw from the

information afforded by these analyses is, th t the condition of iron in respect to its so-called "richness" is, within certain limits, entirely independent of its chemical constitution. The assertion just made is not unreserved, because it is generally thought that an excess of sulphur greatly *hardens* iron, reducing it to the lower numbers, and ultimately converting it into "mottled," or even "white." The second inference to be drawn from what has preceded, is, that if the composition of the iron does not affect its quality, there is no alternative but to conclude that the change is due to alterations of temperature alone. Corroborative of this opinion is the well-known behavior of iron when suddenly cooled, by which even the richest iron, when run into a *chill*, becomes white; and, again, No. 1 iron, if run slowly from the blast furnace, may be reduced in physical appearance to No. 3.

It would appear, judging from the above analyses of Cleveland iron, that the metal, on being fused in the blast furnace, takes up a quantity of carbon, varying from a trifle above 3 to a trifle under 4 per cent., and that the actual quantity does not appear to exercise any influence in determining the nature of the product.

In the fluid state, I conceive the carbon, so taken up, confers upon the iron the property of fusion much below the temperature at which the pure metal melts, and the carbon itself may be regarded as dissolved in the iron. If, during the process of manufacture, the pig metal has been formed at a low temperature, consolidation, I imagine, takes place under such circumstances that the crystals are so minute, and the carbon which is separated assumes the uncombined or graphitic form in particles so minute as to be invisible, and in consequence, the iron is white. If, on the other hand, the furnace is working at a very high temperature, the intensely heated iron crystallizes with large facets, upon which the extruded carbon assumes the condition of distinct plates or flakes.* Should the temperature be less intense, these crystals are of smaller dimensions, and the separated carbon is less conspicuous, and, as the temperature of the furnace declines, the crystals decrease in size, as do the flakes of carbon, until both disappear in white iron.

Exp. 647. I endeavored to prove the correctness of this view by direct observation on the blast furnace itself. The immediate vicinity of the tuyeres is, of course, the focus of greatest heat, which diminishes rapidly in intensity at a very short distance higher up in the furnace. At a point about 6 ft. above where the blast is admitted, the heat is one of very bright redness, almost white, and certainly quite enough to melt cast iron. I expected some of the iron would be fused at this locality, and, not having encountered the highest temperature of the hearth, would be white. A hole was drilled 6 ft. above the tuyeres in the side of the Wear furnace; some lbs. of fluid iron ran out, all of which was perfectly white, although the produce from the ordinary tapping hole upon the occasion of the experiment, was foundry gray No. 3.

Anyone with the slightest acquaintance with an iron furnace is aware that if the burden of mine is raised beyond a certain point, the slag acquires a black color, deepening in intensity as the excess of ore is increased. This is simply due to unreduced oxide of iron passing into the slag; and, being desirous of knowing whether the presence of a greater or less quantity of this oxide affected the quality of the iron, I had a number of analyses of slag made while the Clarence and Wear furnaces were working on known qualities of iron.

When running No. 1 iron, the slag contained of Fe per cent.:—

Exp. 648.	Exp. 649.	Exp. 650.	Exp. 651.
.71	1.06	.89	.44
Exp. 652.	**Exp. 653.**	**Exp. 654.**	**Average.**
.28	.27	.52	.59

When running No. 3 iron, the slag contained of Fe per cent.:

Exp. 655.	Exp. 666.	Average.
.84	.33	.58

When running No. 4 iron, the slag contained of Fe per cent.:

Exp. 667.	Exp. 668	Exp 669.	Exp 670.
.54	.47	.69	.58
Exp. 671.	**Exp. 672.**	**Exp. 673.**	**Average.**
.47	.81	1.00	.65

* A very interesting paper, on the occurrence of graphite in cast iron, was read by Mr. G. J. Snelus, of Dowlais. In it, the author states that, by mere mechanical means, a considerable quantity of carbon in this form was separated from the iron,

There is obviously nothing in these numbers to connect the nature of the product with the quantity of iron in the slag.

Returning, then, to the temperature as the cause of differences in quality of pig iron, the "chilling" of gray metal, and its conversion into white, may be regarded as the effect of preventing, by rapid cooling, the formation of crystals sufficient in size to render their coating of carbon visible.

If a quantity of this white iron is introduced in a cupola, as soon as it is heated to its melting point it fuses, and runs to the bottom of the furnace. On being run out, it solidifies under conditions even less favorable for visible carbon separation than when it was produced in the blast furnace; inasmuch as the temperature of a cupola is below that employed for smelting iron. As might be expected, the iron is still white, at all events when run into masses of moderate size.

If, however, such dimensions are given to the fused mass as to produce very slow cooling, then, in spite of the comparative lowness of temperature, the crystals assume a size which permits separation of carbon in a visible form, and in consequence the iron becomes more or less gray in color.

To prove this, I had a mould made, being a cube of 3 ft., and, therefore, capable of holding 5 or 6 tons of metal. The mould was dried and warmed, and into it was run this quantity of white iron. The whole was then covered up with sand to retain the heat as long as possible. At the end of some days the iron was removed, and by means of a heavy weight falling on a steel wedge placed in a cavity cast to receive it, the block, with one blow was split through the middle.

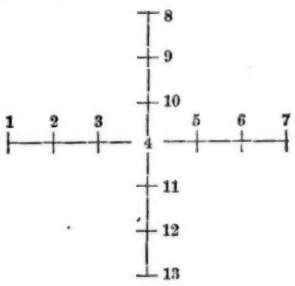
The edges of this fractured surface were white, with a few circular patches of gray; these increased as the centre was approached, and at a distance of 2 or 3 in. from the outside, the color was gray interspersed with patches of white, so that at a little distance it resembled gray granite. One *git* or pouring place, which fed from the bottom upwards, was gray forge at its lower end. Another *git*, which filled an orifice made to permit the air to escape from the top of the mould, was entirely white.

The following four samples were then analyzed:

	Exp. 674. Original pig.	Exp. 675. White git.	Exp. 676. Gray git.	Exp. 677. Near centre of block mottled.
Uncomb'd car.	2.209	2 198	2 472	2.296
Combined ...	.993	666	1.014	.644
Phosphorus ..	1.318	1.344	1.134	1.346
Sulphur	.199	.197	.016	.007
Silicon	.640	.860	.900	.760
Slag	1.460	1 020	.360	.920
Iron by differ.	93.181	93.715	94 104	94.027
	100.000	100.000	100.000	100 000
Iron by anal's	92.650	94 250	93 850	94.500
Total carbon	3.202	2.864	3.486	2 940

The chief alteration appears to be, that remelting has removed more or less of the slag. The phosphorus remains the same; the silicon has increased; and the sulphur in the gray and mottled iron, has notably diminished. The carbon is lessened in two of the cases, and increased in the third.

To ascertain whether the decrease of sulphur in Exp. 676 and 677 was not merely accidental, the block had 2 lines drawn at right angles across the centre of the fractured face, and specimens were drilled out at intervals of 6 in., and numbered thus :—



Of these, a certain number were analyzed, and gave the following results :—

Per cent.	Exp. 678 No. 1.	Exp. 679. No. 2.	Exp. 680. No. 4	Exp. 681. No. 5.
S.....	.234	.218	.195	.234
C comb..	....	....	.626	720
"uncomb.	....	....	2.046	2.008
Total C.	2.842	2.978	2 672	2.728

Per cent.	Exp. 682 No. 6.	Exp. 683. No. 7.	Exp. 684 No. 8.	Exp. 685. No. 9.
S.....	.236	.248	.242	.234
C comb..	.626	.770	....	....
"uncomb.	3.132	2.236	....	....
Total C..	2 738	3.006	2.802	2.776

Per cent	Exp. 686. No. 11.	Exp 687. No. 13.
S	.200	.242
C combined	....	....
" uncombined	....	....
Total C	2.788	3.070

The foregoing experiments were undertaken partly to see whether, as with the Ag and Pb in the case of the Pattinson process of desilverizing lead, any combinations of Fe and those subtances which are associated with it in pig iron, remaining liquid longer than others, might be found to be concentrated in particular portions of the mass.

From these numbers we may regard the whole block as possessing a uniform composition as regards sulphur and carbon.

In order to secure the exposure of some white pig iron to a temperature which was known to suffice for the production of gray, the following trial was made :—

Exp. 688. A furnace running No. 3 iron was selected, and at a point a few feet from the opening where the slag flowed out, a channel and a basin in its course was scooped out in sand, so that when the slag ran down the channel the small reservoir contained a certain quantity in a fluid state. The current was continued long enough to prevent the cold sand materially affecting the temperature of the molten mass, which as usual ran through an external crust. Quite close to where the stream left the furnace, and, therefore, before it had parted with any notable quantity of heat, a bar of white iron was inserted in the current, where it speedily melted, and as the globules of metal dropped off the bar they were carried forward by the slag down the channel until they were intercepted by, and retained in, the basin. In this way they were exposed to heat closely approaching that of the interior of the furnace itself. When a few lbs. were thus carried off, the current was diverted and the iron removed when solid, and found to be No. 3, although not above an inch in thickness.

Exp. 689. A quantity of the iron obtained in the previous experiment was melted in a crucible, and run into a mould having a transverse sectional area of about 1 in., to see whether there was any tendency to re-assume the condition of white iron. It remained perfectly gray, but became closer in the grain; not more so, however, than a specimen of ordinary No. 3 iron, when treated in a similar way.

What the temperature to which this iron was subjected is, I have been unable to determine. One step towards this would have been ascertaining accurately the quantity of heat contained in the liquid contents of the furnace. In this, as has been stated, I have hitherto failed ; but were we in possession of the necessary information, the absence of all data as to the specific heats of bodies at very high temperatures prevents further progress in the estimate.

Exp. 690. The only experiment I performed in the direction indicated, consisted in immersing a piece of bar iron in the slag runner in the manner observed with the white pig iron, the produce of the furnace itself at the time being gray No. 3. It was fused and collected in the basin, still preserving the property of malleability. The melting point of this substance is stated by Daniell to be above 1,800 deg. C. (3,272 deg. F.)*

Kartsen determined that gray iron had a higher melting point than white iron, and mentions that this latter variety might be converted into gray iron by very slow solidification at a high temperature, as well as that gray iron became white on sudden solidification. Dr. Percy† questions the conversion of white into gray iron, under the circumstances described, as a universal law ; but I imagine this difference of opinion may be due to proper precautions as to slowness of cooling not having been observed. So far as my own recollection serves me,

* Daguin (Traité de Physique) gives 1,500 deg. C. as the fusion point of *fer doux*, and 1,600 deg. C. *fer ecroui*, apparently on the authority of Pouillet.

† Percy's Metallurgy, Iron and Steel, p. 112.

this change from gray to white, and a partial change at all events of white to gray (mottled), are facts which were well known to every practical iron founder long before the date of Karsten's paper containing the opinions quoted above, which was written in 1846.

Gurlt, from reasons founded upon certain supposed definite compounds of iron and combined carbon, conceives grayness and whiteness in iron to be determined by their respective compositions, and mottled to be a mixture of the two. In support of this, he speaks of having converted spiegeleisen containing manganese into gray iron by simple exposure to a temperature much higher than its own melting point. What the nature of the change, if any, may be when the metal is fluid, probably no one can say; but so far as its composition after solidification is concerned it would be difficult to ascribe any change in its physical aspect to any alteration either in its content of carbon or in its chemical constitution. This at least is what may be gathered from the analysis of the pig iron used for the large block described in this section, the different portions of which were stated to contain—

Experiments.	Uncombined carbon.	Combined carbon.	Total.
674. White pig iron before fusion, per cent	2 209	.993	3.202
675. White git after fusion	2.198	666	2 864
676. Gray do. do.	2.472	1.014	3.486
677. Centre of block do., mottled	2.296	.644	2.940
680. Do. do. do.	2.046	.626	2.672
681. Specimen 6 in. from centre mottled	2.008	.720	2.728
682 Specimen 6 in. from outside, mottled	2.132	626	2.758
683. Specimen next outside, nearly white	2.236	.770	3.006

According to Gurlt, says Dr. Percy, gray iron is an octocarbide intermingled with graphite, and white iron a tetracarbide. The latter is formed at a low heat, comparatively, and is resolved at a higher temperature into octocarbide and graphite. The Doctor commends Gurlt's theory for its simplicity, but objects to the conclusion which practically makes difference of temperature explain everything.

Unless the numbers indicating the total quantity of carbon in my large cube, as well as those denoting the weight of this ingredient in its so-called combined and uncombined condition, involve a good deal of experimental error, I am disposed to agree with Dr. Percy that it is improbable that the production of one kind of iron depends on the decomposition by temperature of another; but I do feel inclined to adopt the conclusion this author hesitates to consider as founded on truth, viz., that difference of temperature may, and probably does, explain everything.

On the other hand, Karsten, and after him, Janoyer and Percy, appear to have proved that sulphur expels carbon from iron at a high temperature. I have not myself made this question the subject of examination, but I may state it is a matter of belief among practical men that sulphurous coke in the blast furnace, and the use of this kind of fuel in the foundry cupola, so hardens the iron that it is apt to be white towards the edges.

Pig iron, although always containing other matter than iron and carbon, consists essentially of these two elements alone, inasmuch as if perfectly pure Fe_2O_3 is heated with pure C, a substance analogous in character to pig iron is obtained.

The composition of the crude or pig iron of commerce differs, however, considerably from the substance produced under such conditions as those just described, and as the elements other than those previously named, and which may be regarded as impurities, are of course derived from the minerals used, the extent of such contamination will in a great measure depend on the quality of the fuel, ores, and flux employed in the blast furnace.

Although the substances which enter a blast furnace may be, and are, very numerous, it by no means follows that they of necessity find their way into the pig iron. What the circumstances are which determine the absorption of varying quantities of some of them by the metal, our knowledge of the process is at present too limited to pronounce.

Phosphorus, under all circumstances, as we have seen in the previous section,

may be assumed as being almost entirely taken up by the iron; whereas sulphur, by the copious use of lime and a high temperature, is almost as completely found in the slag.

Manganese, when a constituent of the ore, is found partly in the iron and partly in the slag. Upon one occasion* when using an admixture of a manganiferous ore, containing 30 per cent. Mn and 17 per cent. Fe, with the Cleveland stone, I found the different qualities of iron contained

	No. 1 pig.	No. 2. pig.	No. 3 pig.
Manganese	1 75	2.31	2 45
Carbon	2.94	2.90	3.30
Sulphur	.292	.247	.254
Phosphorus	.416	.860	.867

The slag produced at the time of the addition of this manganiferous ore contained:

Si	29 25
$Al_2 O_3$	19.25
$Ca O$	38 25
$Mg O$	.60
$Fe O$	1.04
$Mn O$	8.76
Si	2.16
$Ti O_2$	.75
	100.000

By calculation, it appeared, of 100 parts of manganese which entered the furnace, there was

United with the iron	9 5
Found in the slag	87 6
Unaccounted for	2 9
	100

Of the other foreign ingredients, the only one of importance, either from its almost universal presence in, or its effect on, the iron, is silicon.

In the analyses quoted in the present section, it will be observed Si varies considerably in quantity in the iron smelted from Cleveland stone. It has been pretended that this substance is an essential ingredient in pig iron, but looking at some analyses, and at the fact that cast iron may be produced from carbon and pure iron, there seems no good grounds for the assumption.

With regard to the influence of Si on the quality of pig iron, it may be questioned whether it is ever beneficial. Even in moderate quantities the metal itself is undoubtedly rendered weak as a material for the purposes of the founders, and its presence in any quantity in forge iron is undoubtedly detrimental, inasmuch as it not only yields no malleable iron, but, on the contrary, it carries off a large quantity of Fe as a silicate.

From this somewhat general condemnation, I understand, must be excepted a moderate amount of Si in iron destined for the production of Bessemer steel. Here the heat evolved by the generation of SiO_2 is regarded as helping the process, and may also possibly assist in forming a vehicle by means of which some of the other impurities are removed from the product sought for.

Under these circumstances, viz., that the presence of Si at one time and its absence at another are desirable, it becomes a subject of some interest to inquire what are the conditions which are most conducive to the reduction of SiO_2 and the absorption of its base by the iron.

With the exception of Exp. 646, in which Si appears in excessive quantity in a specimen of white iron, its presence is promoted by a high temperature, which is, as might be expected, favorable to the decomposition of SiO_2, because, as a rule, the "richer" the iron the more Si is there in the pig, and we have seen "richness" is acquired at the expense of heat. Thus the percentage of Si is in—

Making No. 1.		Making No. 3.	
Exp. 638	1.683	Exp. 641	1.372
" 639	1.585		
" 640	1.634		
Average	1.634		1.372
Making No. 4.		**Making white.**	
Exp. 642	1.531	Exp. 644	.640
" 643	1.352	" 645	.900
Average	1.421		.770

There occurs, however, occasionally, at most ironworks, a state of things which leads to the production of a kind of iron known in the north of England under the name of "glazy metal." This variety of pig is gray in the fracture, somewhat leaden in its aspect, and is composed of small crystals. With these peculiarities well marked, it is scarcely too much to say, the article is almost entirely worthless. In castings it is weak to rottenness, and in the puddling furnace it melts like water, and so completely defies the ex-

* Report to British Association, 1863, I. L. Bell.

ertion of the puddler, that his "fettling" disappears long before the obstinate material he is operating on shows any signs of "coming to nature."

I have known a furnace go upon this quality of iron, and before its condition came to my knowledge, make a couple of hundred tons of this valueless substance. The cause of its appearance is generally considered to be dependent on excessive heat in the furnace—at all events, raising the burden of the ore, or lowering the temperature of the blast, which latter has the advantage of being a readier mode of cure, always puts an end to its production.

Two specimens of glazy iron were analyzed, and found to contain*—

Fe	88.18	90.70	S	.17	.23
C combined	.79	.71	P	1.12	1 12
C uncomb'd	2.59	2.68	Ti	.26	.18
Si	5.13	5.13	Ca	.22	.20
Mn	.77	56	Mg	.06	.03
				99.29	101.54

* I. L. Bell: Report to British Association, 1863.

From what has preceded, it seems within our reach to avoid deteriorating the quality of our iron by an excessive amount of Si, by avoiding too high a temperature; but, on the other hand, as the "richer" kinds of iron are dependent for their production on the application of more intense heat than the lower numbers, the same cause which gives us "rich" iron may increase its content of Si, and hence the difficulty of our altogether avoiding the presence of this substance. This is particularly the case in Cleveland iron, which, from what I consider the comparative infusibility of the slag which accompanies its production, requires, in my opinion, a somewhat higher temperature than that demanded in the treatment of more silicious ores. A portion of the silica exists in its combined form in the ore, and this also may promote the readiness with which this constituent is decomposed, and thus account for the somewhat excessive quantity of Si in the pig iron made in the district in question.

STEAM TRAMWAY CARS.

From "The Engineer."

It is indisputable that the tramway system is on the whole successful in London, so successful at least that its extension is simply a question of time. Of course, there are people opposed to tramways who write to the "Times" and tell its readers that the wheels of their broughams are broken, and that their horses are lamed by the grooved iron track laid in some of our metropolitan roads. But tramways are not intended to please the owners of broughams and horses, but an infinitely more numerous class; and the members of this class like the tramways very much indeed, and advocate their extension to districts in which nothing but the omnibus or the cab is now to be found. Successful as the tramway system is, it is nevertheless obvious that it is open to improvement, and it is certain that the improvement will be effected. We shall have better rails better laid, and improved cars, and more comfort, and cheaper fares, and larger dividends for the shareholders; but about the rails, the cars, or the dividends, it is not our purpose to speak at present; instead, we propose to consider the possibility of getting rid of horse labor altogether, and propelling our street tramway cars by steam power. A great deal of misapprehension exists on this subject, which is not confined to the minds of the general public. On the contrary, men who ought to know better have not hesitated to say that the thing is impossible. That this opinion has no sound basis we shall endeavor to show. The principal objections urged against the use of steam on our tramways are, firstly, that it would render the cars a nuisance, because the steam and smoke would escape into the air, and annoy foot passengers, householders, and others; secondly, that the engines would make a great noise; thirdly, that they would frighten horses; and, lastly, that they would be very dangerous. Every one of these objections was urged against the use of steam on railways thirty or forty years ago, but they did not impede the progress of the railway system. We think it can be proved that they would not apply at all to properly constructed steam tramway cars.

The best tramway cars now running in London weigh about 2 tons 5 cwt. empty, but we shall be nearly correct if we take the average weight at 2 tons 10 cwt. Forty passengers may be taken to weigh as much more. We have then a gross load of 5 tons as representing the ordinary net weight to be propelled. An average velocity of 6 miles an hour will meet all requirements, and at this speed the resistance per ton cannot exceed 10 lbs. on a dead level with the rails clean and dry. As, however, the rails are usually anything but clean, and the wheels are small, we shall take the resistance at 20 lbs. per ton, and therefore assume that a dead pull of 100 lbs. will be required to keep a loaded tramway car in motion at the rate of 6 miles an hour on a level. On inclines the resistance will, of course, be increased. On a rise of 1 in 40 the tractive force must reach 380 lbs. while on an incline of 1 in 30, which is the very steepest hill on which a street tramway is, in our opinion, admissible, it must amount to 473 lbs. It is just possible for two good horses to take a tramway car weighing with its load 5 tons up an incline of 1 in 30 at a very moderate pace. Any motive power in the shape of an engine which will exert a tractive force of 100 lbs. per ton will muc more than meet all the requirements of the most difficult case which it is possible to imagine.

Now a velocity of 6 miles an hour is 528 ft. per min., and this multiplied by 100 lbs., gives 52,800 foot-pounds as the work required to take one ton of tramway car up an incline of 1 in 30. We have seen that the net weight of the tram-car and its load would be 5 tons, consequently the total work to be done would be 264,000 foot-pounds per min., or exactly 8 effective horse-power. A suitable steam engine, boiler, etc., will probably weigh 1 ton 10 cwt.; add this to the weight of the loaded car, and we have 6 tons 10 cwt. The additional power required to deal with the weight of the engine amounts to 79,200 foot-pounds, or 2.4 horse power. The indicated horse power ought to exceed the effective by about ¼; and, making this allowance, we find as the result of our calculations that the maximum power which can by possibility be required in a street tramway car, propelled by steam, is 13-horse power indicated. An engine and boiler weighing 30 cwt. would, with ease, exert double this power for an hour at a time. We need scarcely state that it is quite within the reach of the most ordinary practice to provide an engine and boiler which shall not weigh more than 30 cwt., and yet will suffice to meet the most extraordinary demands that could be made on its powers of propelling a tramway car. Now let us see how much power would be required under ordinary circumstances. The answer is ready to our hand. Two good horses do the work; and, allowing that each of these animals exerts 75 per cent. of an indicated horse power—which is over the mark—we still find that an engine working up to a little over two indicated horse power, would do all that is generally required. The steam engine fitted to the tramway-car should therefore have cylinders so large that at 6 miles an hour it might exert 13-horse power if a short bit of incline had to be surmounted, as, for example, in crossing a steep bridge; but under ordinary circumstances these cylinders would be worked very expansively by the aid of the link motion. The result would be that the blast would be so far softened that the escaping steam would make little or no noise. Another and most important advantage conferred by the large cylinders would be the power of starting the car rapidly into motion. A speed of 6 miles an hour is 8.8 ft. per sec., and this is very nearly the velocity which would be acquired by the car in falling through a distance of 1 ft. Most of our readers will, we think, understand us when we say that these figures prove that to get the car into motion at the rate of 6 miles an hour 14,560 foot-pounds of energy must be expended over and above the force required to overcome frictional resistance, this 14,560 foot-pounds remaining stored up in the car, to be given out again when it is being brought to rest. If the work of starting the car from a state of rest to one of motion be performed in 10 sec., it follows that during each sec. 1,450 foot-pounds of work must be done, or say, 2.6 horse power. From which it will be seen that on a level the engine should exert about 2½ times more power at starting than will be required when the normal velocity has been attained. All this is perfectly consistent with working conditions. There is not, in a word, the slightest difficulty in designing engines and boilers, which

will comply perfectly with the required stipulations as to weight and power. If any proof of the truth of this statement is required, it may be found in the fact that Messrs. Shand and Mason's Light Brigade engine, weighing complete, with carrying wheels, framing, hose-reel, etc., 35 cwt., has indicated 33-horse power with ease. There is no trouble, therefore, in producing an engine and boiler alone weighing more than the fire engine complete, which would, if needful, work up to 13-horse power, while their normal power would not necessarily exceed from 2-horse power to 5-horse power indicated. As regards the nuisance question, we have already shown that the "beat" of the engine would be almost entirely got rid of. It would be quite removed by turning the waste steam into a large cast-iron hollow deflector, as is done in Field boilers, from which it would escape continuously, highly superheated and completely invisible. If good selected coke was used as fuel, no one in the street or in the car need be aware that a steam engine was used at all. In proof of this statement we may refer to Messrs. Moreland's steam rollers, in which the waste steam is superheated as we have described. Nothing whatever can be seen coming from the chimney, even when the engine is working to its greatest power.

The danger theory does not deserve a word of refutation, in so far as it refers to the chance of accident to those within or upon the cars, caused by a failure of the boiler or machinery. As regards the chance of accident by collision, that is purely a question of brake power. To stop the car would require precisely the same expenditure of energy as was needed to impart a velocity of 6 miles an hour —or, in other words, 14,560 foot-pounds. The co-efficient of friction on a tram rail —which is always more or less gritty— cannot be much less than 1-6 of the load. The load in the case we are considering is 6.5 tons, or 14,560 lbs., and 1-6 of this is 2,426.6 lbs. Each foot therefore traversed by the vehicle with the brakes hard on will represent 2,426 foot-pounds of energy expended in overcoming the friction between wheel and rail, in round numbers, and dividing 14,560 by this, we find that the car can be stopped on a level in a space of about 6 ft., which is less than that in which an existing car or a common omnibus can be pulled up. With common care on the part of the driver no accident whatever could occur from collisions.

We believe that we have made out a good case so far as we have gone for the steam-propelled omnibus, although we have not said a syllable concerning the advantages it holds out to shareholders and others. These and one or two other points we shall probably deal with in future articles.

THE BRITISH COAL COMMISSIONERS' REPORT.

From the "Quarterly Journal of Science."

The question which gave rise to the appointment of the Royal Commission, whose Report* we are now about to review —namely, the probable duration of the coal resources of the United Kingdom— was, according to Mr. Jevon's account,† first raised by one John Williams, a mineral surveyor, who, in a work published by him in 1789, entitled "Natural History of the Mineral Kingdom," gave a chapter to the consideration of "The Limited Quantity of Coal of Britain." At that time the coal production of the United Kingdom amounted only to about 7,500,000 tons annually. This subject was also referred to by Sir John Sinclair, in his "Statistical Account of Scotland," and again in 1812, by Robert Bald, in his "General View of the Coal Trade of Scotland." Later still, Dr. Buckland prominently brought it before the public, both in his evidence before the Parliamentary Committees of 1830 and 1835, in his "Bridgewater Treatise," and again in his address to the Geological Society, on the 19th of February, 1841. Up to this time, however, the public generally did not express any great interest in the matter; and it was not until the publication of Mr.

* Report of the Commission to Inquire into the several Matters relative to Coal in the United Kingdom, July 27, 1871.

† The Coal Question: an Inquiry concerning the Progress of the Nation, and the Probable Exhaustion of our Coal Mines. By W. Stanley Jevons, M. A., etc. 1866.

Hull's work* on the subject, in 1861, that its real importance began to be better appreciated. This was shortly afterwards followed by Sir William Armstrong's celebrated address as President of the British Association, at Newcastle, on the 26th of August, 1863, in which he stated that "the entire quantity of available coal existing in these islands has been calculated to amount to about 80,000 millions of tons, which, at the present rate of consumption, would be exhausted in 930 years; but, with a continued increase of 2½ millions of tons, would only last 212 years." This announcement, by which the real importance of the question was put before the public in a practical shape, caused at the time considerable excitement throughout the country; and it soon became clear that some confirmation or refutation of the statistics first published by Mr. Hull in his work above referred to, and subsequently promulgated by Sir William Armstrong, was desirable in the public interest. On the 12th June, 1866, the subject was brought before the House of Commons, by Mr. Hussey Vivian, in a very able speech, in which he moved for the appointment of a Royal Commission to inquire into several questions connected with the coal resources of the United Kingdom. This motion was agreed to, and on the 28th idem, the Commission was accordingly appointed, consisting of fifteen members,† with the Duke of Argyll as Chairman.

The special instructions to the Royal Commission were as follows :—

"To investigate the probable quantity of coal contained in the coal-fields of the United Kingdom, and to report on the quantity of such coal which may be reasonably expected to be available for use.

"Whether it is probable that coal exists at workable depths under the permian, new red sandstone, and other superincumbent strata.

"To inquire as to the quantity of coal at present consumed in the various branches of manufacture, for steam navigation, and for domestic purposes, as well as the quantity exported, and how far and to what extent such consumption and export may be expected to increase.

"And whether there is reason to believe that coal is wasted by bad working, or by carelessness, or neglect of proper appliances for its economical consumption."

The first act of the Commissioners was to form amongst themselves five committees for the following purposes:—

1. A. Committee on possible depths of working.
2. B. Committee on waste in combustion.
3. C. Committee on waste in working.
4. D. Committee on the probability of finding coal under permian, new red sandstone, and other superincumbent strata.
5. E. Committee on mineral statistics.

Without confining ourselves in any way to the order in which these Committees subdivided the several questions submitted for their investigation, we now proceed to give briefly the results arrived at by them, and which have been embodied in their respective reports, or brought out in the evidence taken by them.

There is but little reason for doubting that British coal was used in small quantities in the days of the Roman occupation of these islands, as it has been found amidst the remains of Roman civilization in the city of Uriconium and elsewhere. Statements respecting the use of coal before the twelfth century are, however, exceedingly fragmentary; since that period there is tolerably ample information to be obtained respecting the coal trade from the rivers Tyne and Wear, but very little relative to the production at this period of coal in other parts of the kingdom. The first record dates back to the year 1180, when Bishop Pudsey, of Durham, granted some land to a collier, to provide coals for a smith at Coundon, in the county of Durham; similar grants being also made at Sedgefield and Bishop-Wearmouth. In 1213, a charter was granted by King John to the men of Newcastle to dig coal. The earliest record of coal being used in the south of England is in 1279, when coal was purchased at Dover for the use of the Castle. In the year 1300 coal was used in quantity by the brewers and smiths of London; which was, however, prohibited in 1306, on the ground of its being an intolerable nuisance, but fifteen years after-

* The Coal Fields of Great Britain. By EDWARD HULL, B. A. 1861.

† Sir R. J. Murchison, Sir W. G. Armstrong, Messrs. H. H. Vivian, G. T. Clark, J. Dickinson, G. Elliott, T. E. Forster, J. Geddes, R. Hunt, J. B. Jukes, J. Hartley, J. Percy, J. Prestwich, A. C. Ramsay, and J. T. Woodhouse.

afterwards it was used in the Royal Palace. The first Government tax was laid on coal as early as 1379, amounting to twopence for every chalder;* but in the reign of Elizabeth it was raised to twelvepence per chalder, which was regularly enforced to the time of Charles II. Duties were laid on sea-borne coal to assist in building St. Paul's church and fifty parish churches after the great fire of London; and in 1677, Charles II. granted to his natural son, Charles Lennox, Duke of Richmond, and his heirs, a duty of one shilling a chaldron on coals, which continued in the family until it was purchased by Government in 1799, for the sum of £400,000. This impost was known as the "Richmond shilling," and produced soon after it came into the hands of the Government £25,000 a year.

The practice of coal mining had arrived at such a degree of importance at the beginning of the eighteenth century, that we find treatises published as guides to the system of exploration. Many of the collieries were then extensive, and accidents were not unfrequent. An account is given by one author† of a "blast" which occurred in October, 1705, when "there were above 30 persons, young and old, slain by a blast, perhaps in less than a minute's time."

In 1771 there was formed a combination among the coal owners who shipped their coal by the three rivers, the Tyne, the Wear, and the Tees, to raise the price of coals to consumers by restricting the quantity supplied. This combination, known as the "limitation of the vend," lasted with, but a few temporary interruptions, until 1845. As this restriction did not apply to coal shipped to foreign parts, it frequently happened that coal was sold to foreign markets at 40 per cent. under the prices in the London market. About 1791 a feeling grew up in favor of obtaining coal from the midland and other coal-producing counties for the London market.

Coal was first worked in Cumberland, at Whitehaven, by Sir John Lowther in 1660, but there does not appear to exist any record of the quantity raised until towards the end of the 18th century. Little appears to be now known of the early history of the Lancashire coal-fields. In the Cheshire coal-field, coal is said to have been first opened in Nerse township in 1750. The early history of coal mining in Yorkshire is very obscure; but it is stated in an early number of the "Leeds Intelligencer," a local newspaper, that in 1752 a petition was prepared for Parliament for rendering the Calder navigable, the chief object being the conveyance of coal. The Derbyshire coal-fields are referred to by Pilkington,* who wrote in 1789; and Cambden, in his "Natural History of Warwickshire," A. D. 1730, was perhaps the first to record any facts relative to what is known as the Staffordshire coal district. Shropshire from a very early period appears to have yielded from its stores fuel for the use of man. Shropshire coal has been found in the ruins of Uriconium. The earliest record of any colliery workings in this county, however, appears in the "Leeds Intelligencer" for November 23d, 1756. The first notice of the production of coal in the Forest of Dean appears to be supplied by the records of the Justice Seat held at Gloucester in 1282, where it is stated that sea coal was claimed by 6 of the 10 bailiffs of the Forest of Dean. Coal was sent to London from South Wales as early as 1745, and in North Wales the Mostyn Collieries date from the 23d year of the reign of Edward I. Amongst the earliest reliable accounts of the Scotch coal-field, we find that in the 12th century, William de Vetereponte granted to the monks of Holyrood, "totam decimam de carbonaris meo de Carriden." This is the name of a small brook flowing into the Frith of Forth, about 3 miles north of the ancient palace of Linlithgow. This was in the time of William the Lion, during whose reign the monks of Newbattle worked coal on the margin of the Esk. Arthur Dobbs, author of an "Essay on the Trade of Ireland," writing in 1728, says, "We have of late discovered coal mines in the counties of Cork and Leitrim."

Having thus, in the briefest possible manner, touched upon the early history of the coal-fields of the United Kingdom, we pass on now to notice the amount of coal

* This was probably the Newcastle chalder, containing 53 cwts. of coal.

† The Compleat Collier; or, the whole art of Mining and Working Coal Mines, etc., as is now used in the Northern Parts, especially about Sunderland and Newcastle. 1708.

* A view of the present state of Derbyshire with an account of its most Remarkable Antiquities, etc. By James Pilkington. Derby, 1789.

that has been raised from time to time. The estimated production of the whole Kingdom is thus given in the Commissioners' Report :—

"In the 3 centuries before 1800, it is computed that not less than 850,000,000 tons of coals were raised from the coal-fields of the kingdom. During the next 50 years there was a constant and steady increase in the production, and fully two thousand millions of tons of coal were extracted. Up to this time the records of coal produce were most imperfect and it was not until the year 1854 that reliable returns have been in existence. The average production in 1851, 1852, and 1853, may be taken at 50,875,000 tons per annum. In the years 1854 to 1869, both inclusive, 1,343,793,705 tons were raised, which, added to the figures above given, and estimating the return for 1870 at 110,000,000 tons, show that we have already drawn from our original stores of fuel not less than 4,456,000,000 tons* of fuel."

Space will not admit of our entering into any minute detail regarding the consumption of coal, but it may be stated that, of the 107½ millions of tons raised in 1869, 32,446,506 tons were employed in iron manufacture ; 25,327,213 tons in manufactures; 3,277,562 for steam navigation; 2,027,500 for railways, locomotives, etc.; 18,481,572 in domestic consumption; and 9,775,470 tons were exported.

Large portions of some of our coal-fields lie at a greater depth than has yet been reached in mining, and it is considered that the increase in temperature which accompanies increase of depth is the only cause which it is necessary to consider as limiting the depths at which it may be practicable to work coal. In this country the temperature of the earth is constant at a depth of about 50 ft., and at that depth the temperature is 50 deg. F. The rate of increase of the temperature of the strata in the coal districts of England is in general about 1 deg. of Fahrenheit for every 60 ft. of depth. The depth at which the temperature of the earth would amount to blood heat, or 98 deg., is about 3,000 ft. Under the long wall system of working, a difference of about 7 deg. appears to exist between the temperature of the air and that of the strata at the working faces, and this difference represents a further depth of 420 ft.; so that the depth at which the temperature of the air would, under present conditions, become equal to the heat of the blood, would be about 3,420 ft. Beyond this point the considerations affecting increase of depth and temperature become so speculative as to render it necessary to leave the question in uncertainty ; but, looking to possible expedients which the future may elicit for reducing the temperature, it is considered that it may fairly be assumed that a depth of at least 4,000 ft. might be reached.

Before considering the supplies of coal which still remain for consumption, within a workable depth, it is necessary to refer briefly to the waste that now occurs in working, and through imperfect combustion.

The theoretical value of 1 lb. of coal is 14,000 units of heat, which, if properly applied, should be equal to the power of lifting 10,800,000 lbs. 1 foot high, whilst the highest practical result which has been realized is 1,200,000 lbs., or less than one-eighth of the theoretic value, and this without counting the impurities of ordinary coal, which cannot be taken at less than 10 per cent. *Theoretically*, 1 lb. of pure coal should evaporate about 13 lbs. of water ; *practically*, 1 lb. of ordinary coal does not evaporate 4 lbs. The best results are stated to have been obtained in the boilers of Cornish engines, or in boilers constructed upon the model of the "Cornish boiler." The "duty" of the best Cornish engines since 1814 shows that, up to a certain point, there was a gradual increase in the number of pounds lifted 1 ft. high by the combustion of 1 bushel (94 lbs.) in the earlier tables, and of 1 cwt. (112 lbs.) in the latter ones ; and that, after the maximum had been obtained, there was a steady decline in the effective power obtained ; but the highest recorded duty is about 98,300,000, in 1857. Upon the general question of coal consuption, the conclusion arrived at by the Commission is that "for some time past, in our manufactures, there have been constant and persevering efforts to economize coal, by the application of improved appliances," and there is reason to believe that, "in some branches of manufacture, the limits of a beneficial economy appear to have been nearly

*The Report says 4,300 millions of tons, but in this figure he returns for the 3 years 1851 to 1853 appear to have been omitted.

reached, and that in other cases a gradual effort would continue to be made for saving fuel." It may be assumed, therefore, that the progress of economy in using coal is not likely to operate in future with greater effort in keeping down the increase of consumption than it has hitherto done. The present consumption of coal for domestic use is generally estimated at 1 ton per head of the whole population, and the future increase under this head may be expected to coincide with the increase of population; whilst, as regards the future exportation of coal, there is reason to doubt whether much further increase will take place in this direction, owing to the steady development of the coal-fields in other countries.

With regard to the available supplies of fuel yet remaining, a not unimportant consideration is the amount of waste incident to mining coal. It is clear from the evidence adduced on this subject, that, although in many instances waste in working is reduced to a minimum, and although manifest improvement is being made in the working of coal, especially by the extension of the system of "long wall," nevertheless coal is wasted by bad working and by carelessness, and that to a very considerable amount in proportion to what is actually used. Under favorable systems of working the loss is about 10 per cent., while, in a very large number of instances, the ordinary waste and loss amounts to 40 per cent., irrespective of what is sacrificed by the necessity for leaving coal for barriers, for the support of buildings, and for other objects. This is a very considerable evil, and one which requires immediate attention. If it be necessary to husband our coal resources, means should be everywhere encouraged, not only for the introduction of an improved system of getting coal, so as to reduce the waste to a minimum, but for the better utilization of small coal, none of which should be permitted to be left below that can possibly be raised. One method of utilizing small coal, which is briefly referred to by Committee E in their Report, is by the manufacture of patent fuel; but this is not at present carried on to a sufficient extent to have much effect upon the general question.

In considering the quantity of coal in known coal-fields, 4,000 ft. has been adopted as the limit of practicable depth in working, and a certain proportion has been allowed for waste and loss incident to working the coal. With these provisions, the estimated quantity of coal in the ascertained coal-fields of the United Kingdom is 90,207 millions of tons, whilst at depths below 4,000 ft. it is computed that there is a further supply amounting to 7,320 millions of tons, which might be obtained if existing obstacles to working at a lower depth than 4,000 ft. were overcome. Space will not admit of our even touching on the considerations upon which the Commissioners express themselves in favor of finding coal under the permian and newer strata. The supply from this source, within the depth of 4,000 ft., is roughly estimated at 56,273 millions of tons. It is considered probable that coal measures may possibly extend beneath the south-eastern part of England; but Sir Roderick Murchison contends, in opposition to this theory, that "in consequence of the extension of Silurian and Cambrian rocks beneath the secondary strata of the south-east of England, and of the great amount of denudation which the carboniferous rocks had undergone over the area of the south of England previous to the deposition of the secondary formations, little coal could be expected to remain under the cretaceous rocks." As this question is still one of theory, no attempt has been made by the Commission to estimate the quantity of coal lying under the unexplored area of the south of England.

Omitting the probable amount of coal below 4,000 ft. in depth, there thus appears to be an aggregate quantity of 146,480 millions of tons which may be reasonably expected to be available for use; and it remains now only to see how long that quantity, with an increasing consumption, is likely to last. The bases upon which calculation may be made, as to the probable duration of our coal supplies, are numerous, and varying conclusions have been consequently arrived at by different authorities. The two great principles upon which such a calculation should be based are—the annual increase in population, coupled with the increase in consumption of coal per head of the population. Now from the year 1811 to 1821 the increase in population was 16 per cent., while in the last decade, from 1861 to 1871, it was 11¾ per

cent. These two rates of increase, in conjunction with those of the intervening decades, have been taken as the elements of a curve, which, carried forward, shows the extent of the population in future years, supposing no disturbing causes to arise. The rate of consumption of coal per head of the population appears to have been very irregular; but, on an average, the increase in fourteen years amounts to nearly 3 per cent. per annum, but it is not thought probable that this rate will be maintained. From statistical tables furnished by the Commissoners, it appears that the absolute increase of the consumption of coal between 1855 and 1859 averaged 0.035 ton per head per annum; that the next six years 1859 to 1865, averaged 0.145 ton per head per annum; while the last four years, 1865 to 1869, only averaged 0.0463 ton per head per annum. From this it would appear that the annual increase has passed through a point of maximum increase, and that it is now diminishing.

Basing their calculation, however, upon an arithmetical instead of a geometrical increase in the rate of consumption, and simply adding a constant quantity equal to the average annual increase of the last 14 years, taken at 3,000,000 tons, the Commissioners arrive at the following result, namely, that at the end of 100 years the consumption would be 415,000,000 tons per annum, and that the now estimated quantity of coal available for use would represent a consumption of 276 years. Taking, however, another view of the case, and supposing that from this time the population of the whole country and the consumption of coal per head of that population will remain constant, or merely oscillate without advancing, our available coal would represent a consumption of upwards of 1,273 years, at the rate of 115,000,000 per annum.

These two calculations, as to the probable duration of our coal resources, given by the Coal Commission in their Report, may probably be taken to represent two extreme cases, between which the actual truth may probably be found. Whilst, then, we may confidently anticipate the continued existence of coal for some 300 years at least, it by no means follows that its price will remain as at present. With increased depth of workings, and an increased difficulty in raising coal, its price must necessarily rise; and although, therefore, there is no fear that coal will become actually scarce in our time, the same effect will, in a great measure, be secured by its increase in price. The prevention of this evil can, apparently, only be effected by still greater economy in combustion, and the enforcement of a law that no coal, either large or small, shall ever be left in a working beyond what it may be impossible to gain.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.

From "The Mechanics' Magazine."

The following is an abtract of a paper read before the Institution of Civil Engineers in London, by Mr. Geo. Gordon, C. E.:

The author gave an account of the ancient native and the modern systems, under the two heads of Tank and Channel Irrigation. The existing Tank Irrigation was chiefly ancient, and comprised innumerable tanks of all sizes, from what might be termed lakes downwards. These might be divided into three classes: 1. Those formed by the closing of the passage of a considerable river through a narrow gorge, in a range of hills, by means of a high dam or "bund." 2. Those formed in the plains, by embankments carried across the drainage of the country, and impounding the water of one or more streams; these tanks being often of great superficial area but shallow. 3. Tanks which might be considered intermediate between the other two, having in general a greater length of dam than the first, and a greater depth of water than the second. Few examples of the first kind remained entire. A description was given of the ruined Mudduk Masoor Tank, one of this class situated on the borders of Dharwar and Mysore, of which the following were the principal dimensions: Length of the main bund on the crest, 550 yards.; present height from 90 ft. to 108 ft.; width at the base, from

945 ft. to 1,100 ft.; area of the lake at 90 ft. depth, 40 square miles; contents about 1,400 million cubic yards of water. The area of the drainage basin, which was on the inner slopes of the Western Ghats, was 500 square miles. The author was engaged on a proposed restoration of this tank; but it was found that the present average rainfall would not suffice to fill much more than one-half of its ancient basin, and it was suggested that the depth should be reduced from 90 to 70 ft. This diminution in the supply was supposed to be attributable partly to the diminished rainfall and partly to the construction of small tanks on some of the feeders, at a date subsequent to the completion of the Great Tank, which was assigned, by tradition, to the 14th or 15th century. The main bund was supplemented by two smaller ones, placed on saddles at some distance from it, in the range of hills; and it was by the breaching of one of these that the tank was ruined, as the principal embankment remained entire. There were no traces of a waste weir or by-wash of any kind. The second and third classes of tanks were then described, some ancient ones of great dimensions being noticed, such as the ruined Poonairy Tank, in the Trichinopoly district, of which the embankment was 30 miles in length, and the Veeranum Tank, still in action, with a bund 12 miles long. Under the head of Channel Irrigation, it was stated that only rivers of the larger class, which had a continuous flow for several months, were available for extensive irrigation projects. The smaller rivers were merely torrents, which quickly carried off heavy falls of rain, and then became dry again. The water, however, was in many cases intercepted by chains of tanks, of the second or third class, built across these torrents.

The deltas of large rivers, being the most easily irrigated lands, had been so treated for ages, and the works had been much extended and improved under the British Government, by the construction, by their able engineers, of permanent weirs of great lengths, at the heads of the deltas, such weirs being built on the sandy beds of wide rivers subject to heavy floods. This seemed to have been beyond the skill of the ancient native rulers. They, however, built many weirs on the large rivers in the middle part of their courses; the situations being skilfully chosen, but the construction was rude and imperfect. They were generally built on a reef of rocks, with loose rubble, faced with large blocks of granite laid dry, and sometimes fastened with iron clamps. The modern weirs in similar situations were of masonry, with a vertical or slightly battering face on the down-stream side, and with heavy copings. In rivers having sandy beds, it was usual to build the body of the weir on a foundation of brick wells, sunk to the low water level, and filled with concrète. On the lower side there was an apron, having a slope of 1 in 12 from the crest, with a toe wall; and if the slope was long, intermediate walls were also built on wells, and below all there was a broad layer of rough rubble of large dimensions.

The ancient irrigation channels were generally defective in design, being too small, and having much too great a fall. In consequence of these channels being so near the river, they irrigated only a narrow strip of land, and the current being too great, excessive annual repairs were required. This system necessitated numerous offtakes from the river, involving the expense of many weirs, and a great aggregate length of unproductive channel from the offtake to the point where the channel reached such a level as to command the surface of the country. On the other hand, a canal of large dimensions, taken off from one head, having a slower current and less fall, would soon so gain on the level of the river, that it would reach districts remote from it, and consequently more in need of artificial supplies of water; and it would also command a much larger extent of country than it could supply entirely with water. This was an advantage, because it would be many years before a district could be completely changed from dry to wet cultivation, as it would require to have its population trebled. It also afforded means of assisting dry crops in years of drought, and thus preventing famine. In many districts complete failure of the crops now grown occurred every few years, and a good crop was a rare occurrence. There should, therefore, be facilities for completely irrigating detached areas at considerable intervals, and of giving occasional irrigation to dry crops.

Distribution was effected from the sec-

ond class of tanks directly by means of sluices in the bund. From the third, and more especially from the first class, it was commonly effected indirectly; thus, the natural channels of the river or rivers, which had been dammed to form the tank, were used to carry part of the water for irrigation, weirs being built across them at suitable places and artificial channels taken off from above them. By these means the surplus of the water, which was generally wastefully used by the ryots, was saved, being collected by drainage into the stream, and redistributed at the next weir. Distribution was most economically effected from a canal, when the latter ran along a ridge; but as this could rarely be accomplished in the case of a canal taken off from a main drainage, it was next best effected by leading the main distribution channels down the ridges crossed by the canal. Distribution could be carried out in the Ceded Districts for 5s. per acre, including sluices in the main canal, and all necessary road and water crossings, but excluding the cost of terracing the land to prepare it for wet cultivation, this being done by the occupier. The nature of the ground was such, that, in the districts to which the Paper referred, the drainage was effected naturally, no works being required for that purpose beyond small open trenches in the rice fields.

The value of water to the cultivator was shown, first, by contrasting the yield of dry crops with that of rice and sugar cane, from actual experiment. From these it appeared that the net profit per acre on dry crops was 8s. 2½d.; on rice, £4 16s. 10½d., and on sugar cane, £18 6s. 6d. In the two last cases, a very low rate for the water was assumed, viz.: 12s. per acre for each crop of rice, and 24s. per acre for each crop of sugar cane, as provisionally paid by Government. A comparison between dry crops and rice, and dry crops occasionally flooded, was then made, based on the average price of grain extending over five years and deducting one-fourth from the gross value of the crop in the case of dry crops, and one-sixth in the case of wet crops, to cover loss in bad years. Without deducting the water-rate, the difference in the net value of the crops was as follows: between dry crops and rice, taking the most unfavorable comparison, 25s. 7d.; between dry crops and the same occasionally irrigated, 30s. 8d.; and between two dry crops and sugar cane (which occupied 10 months of the year), £8 2s. 8d. But if water was stored, so as to allow a second crop of rice to be grown, the advantages were nearly doubled. The author then showed that, provided a water-rate proportioned to the value of the water were fixed, irrigation would benefit the cultivator to the extent of 8s. 6d., or 50 per cent., and yield a gross return on the outlay of 14s. 9d. per acre; and if water were stored for a second crop, the gain to the cultivator would be 19s. 9d., or more than 100 per cent., and the return to the agency supplying the water 37s. 3d. per acre, the cultivator not having to expend any capital in improvements. Of the 37s. 3d. per acre profit 22s. 6d. was about the sum due to the storage of water, supposing such storage works to be added to distribution works already constructed. It was shown that the cost of large works of irrigation might be safely reckoned at £7 per acre on an average, or £8 15s. if 5 per cent. on one-half the capital for 10 years during construction were added. If the profits made by the application of the water were divided, in the proportion of one-third to the cultivator and two-thirds to the agency supplying the water, works of channel irrigation would benefit the cultivator, as above stated, to the extent of 50 per cent., and would yield a net return of 7.4 per cent. on the capital expended.

With respect to the cost of tanks, the author gave some figures to show that the construction of flat country tanks of the second class, or even of the third class, would offer a very doubtful return, although in some cases it might pay the cultivators to construct them. Great profits had been made by Government in several cases, by restoring or repairing tanks, and also channels which had become ruined; such net profits amounting to from 10 to 45 per cent., and in one instance, which was cited, to 250 per cent. The construction of large storage reservoirs would, the author considered, return a very large percentage on the outlay. Although none of large capacity had yet been constructed, it appeared probable that, in the most favorable locality, 7,000 cubic yards of water could be stored for £1, and in others 4,250 cubic yards, while the restoration (in part) of the ancient

tank of Mudduk Masoor, already mentioned, would yield 9,600 cubic yards per £1.

The loss by evaporation in the reservoirs of 70 ft. and upwards in depth would vary with their depth, and the time in which they were emptied. It was found, by observations of the evaporation in the locality of 3 proposed reservoirs, to vary from 5 per cent. to 7½ per cent. of their contents. A further loss from the same source would occur in the passage of the water to the country to be irrigated, varying of course with the distance, etc. For the purposes of calculation, the correction for evaporation was assumed at 12 per cent., and the quantity of water required for the cultivation of an acre of rice at 5,000 cubic yards. At the most unfavorable rate of storage (4,250 cubic yards £1, and adding, as in the case of the channel works, 25 per cent. for interest during construction) 3,400 cubic yards per £1, the prime cost after all deductions would be £1 9s. 5d. per acre, for giving a second crop of rice, or a crop of sugar cane;—while the cost at the rate at which the restoration of the Mudduk tank was estimated would be 14s. 10d. per acre. Reference to a table in the paper showed that an outlay of £1 9s. 5d. would yield a net return of about £1 1s. This allowed a large margin for the construction of reservoirs in still less favorable situations than the least favorable one which the author had examined. This statement supposed the reservoir to be constructed in addition to a system of distribution works already existing. The author had excluded the subject of navigation from his paper, as no general rule could be laid down, as to whether it could or could not be economically combined with irrigation. With regard to the large and very remunerative works in the Kistna, Godavery, and Tanjore deltas, it was mentioned that the works in the latter yielded, after deducting repairs and 5 per cent. on the capital, 23½ per cent. direct profit, and those on the Godavery from 50 to 60 per cent. These examples were only incidentally alluded to, because all the deltas, were so occupied as to offer no opportunity for new undertakings on a large scale, while in other districts such enterprises would necessarily be more expensive.

The author submitted the following conclusions: 1st. That irrigation would benefit the cultivator to such an extent as to enable him to pay a water-rate equal to two-thirds of the increased value of his crop, and still leave his own profits from 50 per cent. to 400 per cent. in excess of those derived from dry cultivation. 2d. That the most profitable application of capital would be found in the construction of storage reservoirs as an addition to distribution works already in existence, and that these would yield a net return of 46 per cent., after paying one-third of the gross revenue to the existing works, and increasing the revenue of such works by 4¼ per cent. 3d. That the arbitrary water-rate of 12s. per acre was, on the data assumed by Government, insufficient to yield a fair return directly on the average of new irrigation works, unless these included the storage of water for a second crop. 4th. That the profitable employment of capital in irrigation depended chiefly on the recognition of the principle that the water-rate should be fixed with reference to the value of the crop produced by and the cost of the works in each case, and that otherwise many very beneficial projects would remain unexecuted.

MARINE ENGINE CYLINDERS IN THE NAVY.

From "The Engineer."

In our last impression we called the attention of our readers to an interesting paper on compound engines in the navy by Mr. Pratten, and published in the Annual of the Royal School of Naval Architecture and Marine Engineering. We now propose to deal with a paper in the same publication, "On the Marine Cylinder, as fitted in the Navy," to which we have already alluded. We stated, it will be remembered, that the author of this paper —Mr. Seaton—drew a very deplorable picture of the present position of marine engineering as regards our navy; and we cannot better introduce our subject than by explaining that Mr. Seaton's paper

goes from beginning to end to show that nothing can be more unreliable than the cylinders of our largest men-of-war. He begins, curiously enough, by stating that "Perhaps the most important improvements made during the last 10 years in the marine engine have been made in the design and construction of the cylinder," but a few lines further on he says, that "No one will deny the need of still further improvement—no one at any rate acquainted with the lengthy catalogue of cylinders broken year by year in her Majesty's navy." Now, any one who is in the habit of reading the naval and military intelligence of the "Times," must have found mention made occasionally of cracked cylinders or condensers, but it is equally certain that every engineer of experience will attach little importance to statements of the kind made in a way to convey the impression that the cracking of a cylinder is a very unusual event. Indeed engineers whose experience has been confined altogether to the mercantile marine, are not in the position to realize the astonishing frequency of the occurrence in the navy. Judging from their own practice they will be certain to attribute the cracking of a cylinder to priming, and possibly to negligence on the part of the engineers in charge. Mr. Seaton, however, puts the matter in a very different light. He shows that cracked cylinders are the rule rather than the exception. "Experience," he tells us, "teaches that mere thickness of metal will not suffice, for Messrs. Maudsley's heavy castings are no more infallible than Messrs. Penn's light ones," and he cites numerous instances in proof of this proposition. Thus he tells us of one new iron-clad of 800-horse power which arrived at the port where she was to be fitted out immediately after launching, with both cylinders cracked. The Constance cracked one of her cylinders on one of the very few voyages she ever made, namely, the competitive run to Madeira. The radial ribs in the reservoir of the engines of the Tenedos—described in our last impression—are cracked. The engines of the Black Prince suffered much during her first commission, the forward cylinder being cracked extensively in a line parallel to the axis. The Lord Clyde had to come home from the Mediterranean with both cylinders cracked. The cylinders were re-bored and fitted with bushes at great expense. These bushes cracked on the trial trip, and the cylinders had to be taken out and replaced by others of somewhat different design. The unfortunate Magæra, it will be remembered, had both cylinders cracked. One of the cylinders of the Hercules has been cracked within the last few weeks. "More instances might be given," Mr. Seaton adds, "all tending to show that cast iron should not be used alone for the immense cylinders required for our steamers." Even when the cylinders do not break, they score. As an instance we may cite the Agincourt, whose cylinders were deeply scored by merely steaming from Liverpool to Devonport, and making a few trial trips.

Mr. Seaton makes one or two suggestions as to the arrangements to be adopted in future for getting over the difficulty, but they are not very satisfactory. One is that the cylinders should not be bolted down too rigidly, so that they might not only be free to expand and contract, but also be relieved from the chance of strain due to the working of the ship. He adds that the usual plan is to make a firm connection to the front bearers, oval bolt holes at the other end of the cylinder allowing for expansion; but he admits, almost, in the same breath, that fracture of the cylinders takes place in spite of this arrangement. His great remedy, however, is the use of some material other than cast iron. Unfortunately he has not settled what this material is to be. He is not enterprising enough to venture to think that we can make cylinders 120 in. or so in diameter, of steel; but he ventures to suggest a more extensive use of wrought iron in framings and jackets. We reproduce a striking paragraph which puts his views on the subject very clearly:—"We cannot go on much longer without making some decided alteration in construction, for even cracked cylinders become monotonous after a time, and it would be a disgrace to the profession to wait until a coroner's jury had taken the matter in hand. It does not seem such a difficult task to place a cast iron, or even steel, bush in a wrought iron shell, and still, by a judicious arrangement, maintain all the requisite stiffness. Until something of the kind is done we may expect to hear more of cracked cylinders than will be pleasant, and the delay may be the means

of stopping more than one improvement still required to make the engine perfect."

Mr. Seaton's paper is a startling commentary on the conditions and prospects of marine engineering, and it is worth while to consider to what cause the repeated failure of cylinders in the navy is due. It will not do to attribute it wholly, or, as regards our latest vessels even in part, to the working of the hull in a heavy sea. Our iron-clads are much too stiff, thanks to their double bottom, to work appreciably. The true source of the mischief is to be found in the fact that the cylinders are too large and too complex regarded as castings, and the horizontal type of engine is apparently unsuitable for use under the required conditions. We hear little or nothing of cracked cylinders in the mercantile marine, firstly, because the cylinders, as a rule, are much smaller than the monstrous structures in the navy; and, secondly, because they are by preference always arranged vertically, this last statement holding perculiarly true of modern compound engines. We shall be called heretics if we say a word in condemnation of the horizontal type of engine, but we cannot help that. The horizontal engine is excellent in its way, but it is attended with serious disadvantages when made of great dimensions. There is not a portion of the cylinder in equilibrium, so to speak. It is exposed to an endless variety of complex strains, due to its own weight, that of the valve chest and valve hung on to the side, and those of the various attachments, such as steam pipes and exhaust pipes; besides, it is continually traversed by a piston weighing several tons, always tending to settle down to the lowest point, and beyond question exercising a certain tendency to alter the shape of the comparatively thin and weak cylinder to suit itself. It is simply impossible, again, to make large cylinders covers so stiff that they will not spring. Thus the load brought to bear on the lid of a cylinder 100 in. in diameter, and working steam of 40 lbs. total pressure, will not be much short of 80 tons. The lid in springing tends to draw the cylinder sides inwards, and sets up, besides, very awkward strains through the flanges. When a cylinder is disposed vertically much of the difficulty is got over; the weight of the piston, in the first place, in no way affects the cylinder; again, there is no tendency to distortion due to position.

The pull of the valve chest is taken in the line of the axis of the cylinder, instead of at right angles to the piston-rod. In a word, a great number of cross strains are got rid of, and the metal is, so to speak, left more at its ease; while last, and not least, as the cylinder is secured only at the lower end, it is free to expand and contract as it thinks proper, and it is almost entirely spared from any strain due to the working of the ship. It is no wonder, therefore, that we hear little or nothing of cracked cylinders in the mercantile marine. In the navy, however, it is imposible to use vertical engines without introducing evils greater than those which we wish to avoid. In what direction, then, shall we look for immunity from cracked cylinders? We think the answer is sufficiently obvious. It is to be found, first, in reducing the size of the cylinders within reasonable limits and augmenting their number. Thus, two pistons, 70¾in. diameter, have the same area as one of 100 in. in diameter. Of course, by increasing the number of cylinders from 2 to 3 or 4, we introduce more complication, and slightly increase the weight and the space occupied by the engines. On the other hand, however, we could dispense with one or two objectionable features—such as the back piston-rod absolutely essential to prevent scoring in large engines, and we might considerably simplify the framing, and adopt superior methods of fixing the cylinders. The 3-cylinder type, introduced by Messrs. Maudsley and Field, gave sufficiently good results in many cases to render it probable that it could be used more generally with advantage. We frankly confess that we see no way, in the present condition of the arts of construction, of avoiding the fracture of cylinders in engines of enormous power, other than arranging them vertically, or increasing their number and reducing their size within reasonable limits. We cannot adopt the first plan; the second is open to certain objections; but anything is better than the incessant breaking down of machinery on the permanence of which in time of war the whole safety of the nation might hang. The question becomes daily more serious, inasmuch as

many of our most powerful iron-clads are to be without masts and sails. What, for example, would become of the Glatton if she split her cylinders, even in going from one port to another? It may yet happen that reliable steel castings, weighing 25 or 30 tons, can be made; but until then there is little to be hoped for from steel as a material for marine engine cylinders.

FORMULA DEDUCED FROM THE PRISMOIDAL FORMULA, APPLICABLE TO THE LARGE CLASS OF PRISMOIDS MET WITH IN THE CONSTRUCTION OF RAILWAYS.

By D. J. WHITTEMORE, C. E.

Many of the cross-sections, taken for the purpose of measuring the volume of grading required in the formation of railway excavations and embankments, are what may be called three height sections, said heights being the two slope stake heights and the centre line height of the natural surface of the ground above or below the roadway, which roadway is of uniform width, and the slopes on either side have equal angles of inclination. On many railways, 95 per cent., at least, of the cross-sections taken for the above purpose, are of this kind.

Any formula that expresses accurately the volume contained between two such parallel sections, the heights of which are all plus or all minus, that is an improvement over any of the methods now in general use, will be thankfully received by the practical civil engineer.

Applicable to such cross-sections, I have devised the following formula:

NOTATION.

Let the cross section at the end of the prismoid be known as the 1st section, and the one at the other end as the 2d section; then

Let S = ½ sum of slope stake heights of 1st section.
" S′ = ½ sum of slope stake heights of 2d section.
" C = centre height of 1st section,
" C′ = centre height of 2d section.
" W = width of roadway.
" L = length of prismoid.
" V = volume of prismoid.
" r = three times the vertical measure divided by twice the horizontal measure of slope.

Algebraically, express the prismoidal formula, using the above notation, then there will result on reduction the following

FORMULA.

$$\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,r\,W\right\}\frac{L}{4r}=V$$

It is readily seen, that the numerical value of r for any slope, the angle of which is known, may be determined by dividing three times the sine by twice the co-sine of the angle.

In the following formulæ r is given its numerical value, for each of the slope inclinations indicated.

FORMULÆ.

Ratio of slope ¼ to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,6\,W\right\}\frac{L}{24}=V.$

Ratio of Slope ½ to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,3\,W\right\}\frac{L}{12}=V.$

Ratio of slope ¾ to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,2\,W\right\}\frac{L}{8}=V.$

Ratio of slope 1 to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,1\tfrac{1}{2}\,W\right\}\frac{L}{6}=V.$

Ratio of slope 1½ to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')W\right\}\frac{L}{4}=V.$

Ratio of slope 2 to 1 $\left\{(2S+S')C+(2S'+S)C'+(S+S'+C+C')\,\tfrac{3}{4}\,W\right\}\frac{L}{3}=V.$

In applying the above formulæ it would be convenient to have a column in cross-section book for the sum of the slope stake heights of each section, which sum would represent, in the formula, the value of 2 S or 2 S′, as may be required.

This method of computation requires 4 additions, 4 multiplications, and 1 division, or 9 processes in all. Ordinarily 2, and in many instances 3 or 4 of these processes can be performed mentally.

When the ground line of end-section is level, either of the following formulæ may be advantageously used:

$$\left\{(C+C')C'+C^2+(C+C')rW\right\}\frac{L}{2r}=V.$$

$$\left\{C^2+(C+C')(C'+rW)\right\}\frac{L}{2r}=V.$$

When $S=C$ and S' and $C'=0$ the following formula is correct:

$$(C^2+C\,r\,W)\,\frac{L}{2r}=V.$$

When S and C are unequal, and S' and C' each equal $=0$, the following formula can be used:

$$\left\{2SC+(S+C)\,r\,W\right\}\frac{L}{4r}=V.$$

The formula first written is correct for all of these conditions, the latter being simply deductions from it.

THE NAVY OF THE FUTURE.

From "The Mechanics' Magazine."

A semi-official communication to the "Times" prepares the way for an application to Parliament for funds to build a ship of war which possesses the merit of novelty of construction. The new vessel is to carry the armorplating on the bottom, leaving the topsides unprotected, and, to compensate for this disposition of weight, the coals and stores and cables will be above the water-line. She is to be armed with submarine rocket-tubes for the projection of rockets possessing the inherent property of preserving a given depth of immersion, and which will explode a charge of gunpowder or other explosive, on coming into contact with any solid substance, such as a ship, and hence called a "fish" torpedo. Bold as is this newest essay after novelty, we confess that before launching into the enormous expenditure attendant on the building of a bottom-armored ship, we think a few tentative experiments might well precede the outlay, in order to ascertain the properties both of the bottom-armor and of the submarine rocket or fish-torpedo.

It does not appear very clear why a torpedo vessel, of all others, should carry bottom armor unless especial danger be apprehended from her own weapon. We should have supposed that a torpedo vessel had more to fear from the guns of the ship attacked, than from torpedoes other than her own. A torpedo vessel with light upper works approaching an iron-clad would naturally be exposed to heavy artillery fire, against which bottom-armor would be no protection. Indeed, in such a duel, the positions of the armor in the two ships had much better be reversed—the gun-ship be armored below, the torpedo one on top. But there is not a single experiment extant to show what thickness of bottom-armor will resist a given explosive charge. We know that, 150 lbs. of gunpowder, placed 19½ ft. from the bilge of a wooden ship-of-war, drove her bottom through the upper-deck, making a hole large enough to drive a coach and six through. We know also that a charge exploded against a strong submerged target with an iron tank backing, smashed in the air-tight backing, even when the face of the target was uninjured. But what would be the effect of exploding 150 lbs. of gun-cotton or dynamite in contact with the armored bottom of a ship has never been ascertained, as it might easily be by fastening a section of a well-constructed vessel against the bottom of an old ship. We do not know that the bottom-armor would save the ship, even from her own torpedo, which appears to be the chief object.

Then, as to the fish torpedo, no experience has been obtained with it, except a close experiment made at Sheerness, witnessed by very few officers, and by none who had made torpedoes their special study. The fact that its construction and use is a secret, shows that no useful experience has been obtained with it. It is generally known that it has powers of maintaining a given depth of immersion, that it proceeds very slowly through the water, that all control over it is lost the moment it is liberated from the operating vessel, and that it explodes on making contact with any vessel, friend or foe. Now, it follows

from this, that a self-acting dangerous mine being set adrift in the midst of a fleet, and missing its mark, occupies an unknown position a few feet beneath the surface, and may easily come into destructive contact with friendly vessels, if not with the operating one herself whilst performing the gyrations and manœuvres incidental to a naval action. Such a weapon must be a fruitful source of danger to the fleet in which it is carried, unless some means be provided by which its ignition will be effected or prevented on the lapse of the estimated time for reaching the ship aimed at. Even then, great danger may arise from friendly vessels unknowingly intercepting the path of the fish torpedo. Surely, experiments to discover the means of safety might well be conducted with some old vessel, before building an expensive sub-armored ship, to carry a weapon which may subsequently be proved to be more dangerous to its friends than its foes. Meanwhile, we have safe naval torpedoes, requiring but a few thousand lbs. and a few intelligent experiments for their full development. If some of the £15,000 given for the paper describing the fish-torpedo, had been devoted to careful experimental investigations as to the properties of the outrigger and of the towing torpedoes, we should probably long ago have possessed safe naval torpedoes which could be employed by any steamship afloat, however built. As it is, we are rushing into a heavy expenditure in building a novel vessel, without a single tentative experiment to justify the supposition that bottom-armor will be effective against torpedoes, or that a fish-torpedo can be safely and usefully employed whilst no protection is to be afforded to the discharging vessel against guns, which are the only weapons she need fear, except her own.

ON THE STRENGTH OF CEMENT.*

By Mr. G. F. CHANTRELL.

From "The Engineer."

In undertaking to bring this subject before the Society it was understood with the secretary that it was (considering the short time given me to prepare this paper) to be only a short sketch, and more for the purpose of initiating a valuable discussion on a very important subject. It is to be regretted that there yet exists a great deal of ignorance in this part of the country of the value of Portland over Roman cement, the latter being still, in this town, the most commonly used. The great distinction between these two cements is that the former is an artificial product and the latter a natural one, being simply *calcined* limestone, ground to fine powder, containing in general a variable quantity of about 60 per cent. of carbonate of lime or magnesia, with from 30 to 40 per cent. of clay, with small portions of oxides of iron and magnesia. The clay is highly ferruginous in character, which accounts for the quick setting of this class of cements. The Roman cements used in this market are mostly from the neighborhood of Glasgow, from Holywell, South Staffordshire, and in a minor degree from London and neighborhood, such as the Harwich, Southend, Isle of Wight, Medina, Atkinson's, etc., and the various imitations made from lias lime.

The earliest Roman cement was brought out and patented by Mr. Parker, near the close of the last century. A very good example of this cement may be seen in perfect preservation on the west front of Lichfield Cathedral, which is coated entirely with it. This cement was made by the firm of Wyatt & Parker, and the work was done under the directions of Mr. Wyatt, the architect, an ancestor of Mr. T. H. Wyatt, President of the Royal Institute of British Architects, and Architect of the Liverpool New Exchange. The natural cements cannot be relied on for regularity in strength, but the property of quick setting has great attractions to the plasterer for running cornices. Portland cement, if good, is much slower. In London, the use of Roman cement is on the decline, owing to the superiority in the strength and decided economy of

* Read before the Liverpool Polytechnic Society.

Portland, and partly that the stone of which the original "Parker's" cement was made (that from the Island of Sheppy) is not to be had in quantity; formerly it was to be got easily, being a shingle which was well water-worn; only the hard kernel of the stone was left, the softer and more worthless being washed away. As this stone became scarce the cement makers were driven to use the Harwich stone, which is quarried out of the rocky shore; the surface stone being to a considerable extent perforated by that remarkable boring bi-valve, the "Pholas Dactylus," or, as our friends the Germans call it, the "stein bohrer," the stone borer. Occasionally this stone may be seen landing in the Liverpool Docks, being used as a ballast for the grain vessels coming from Harwich, and is always secured by the local cement makers to mix with the Holywell stone. It is easily recognized by its perforated appearance. Many years ago the Scotch cement stone was imported here for the same purpose, the combination making a very superior cement, but the "cannie Scot" found it more profitable to manufacture it than to ship the raw stone.

Portland cement, of which I shall have more to say, is an artificial preparation, consisting of varying proportions, according to quality, of chalk and clay intimately combined. The chemical ingredients of the best selected materials are:

Chalk: lime, 56.5; carbonic acid, 43.0; water, 0.5.

Clay: silica, 68,45; alumina, 11.64; carb. lime, 0.75; oxide of iron, 14.80; soda and kali, 4.0.

The usual mode of preparation is to reduce these, by different mechanical arrangements, with the aid of water, and the quality of the cement depends on the care with which this is done. The mixture is run into reservoirs to settle, the water carefully decanted off, and as soon as it is sufficiently solidified it is in this plastic state made into small balls or bricks, and dried on a hot floor, the space below being coke ovens. These bricks are then placed in suitable kilns, where they are highly burnt with coke to what is technically called clinkers. These are then passed on to the grinding mills.

The intimate combination of the raw material is one of slow and tedious operation; attempts have been made to accomplish this by a dry process, but the success is uncertain and variable. It is sometimes called the German process, and is not not confined to chalk lines merely. A so-called Portland cement is made in the lias lime districts. I am glad to say that this market is now pretty bare of these, what I may term, bastard Portland cements. The manufacturers have had no scruples in grinding up heavy materials purposely to add to the weight and not to the cementitious qualities, so as to bring it up to the weight of genuine Portland. Natural cements, such as Roman and Bath, weigh from 70 lbs. to 80 lbs. per bushel, and London Portland 100 lbs. to 125 lbs. There are manufacturers in these districts who have turned out Portland cements quite up to the London in strength, but I do not find that they are cheaper.

We have had works established in this neighborhood, but they do not seem to have succeeded financially.

The Thames and Medway manufacturers have great advantages in having their raw material close at hand, and having cheap water carriage.

It is to the foreigners we are indebted in the first instance for the very great improvement made in the quality of Portland cement, and this is due to the superior technical education of foreign engineers. They take infinite pains in testing all the cements used by them on public works, a certain standard of strength being specified, and rigidly enforced. The manufacturers who cultivated this export trade found themselves compelled to pay increased attention and care in the manufacture, and the result has been an enormous increase of the trade.

The extensive character of the main drainage works, carried out for the Metropolitan Board of Works, under the direction of Mr. Bazalgette (the well-known engineer), led to the adoption of a regular and careful system of testing of all the cements used on these works, which were commenced some twelve years ago.

I have the advantage of the tables of results, carefully made by Mr. John Grant, M. Inst. C. E. (who was associated with Mr. Bazalgette), and published by him in the 25th vol. of the "Transactions of the Institution of Engineers," and also

in the more recent ones in the 32d vol., session 1870-71.

The following is the first specification as to the quality of cements used on these works:—"The whole of the cement to be Portland cement of the very best quality, ground extremely fine, weighing not less than 110 lbs. to the striked bushel, and capable of maintaining a breaking weight of 400 lbs. seven days after being made in an iron mould of No. 1 form, and immersed six of these days in water."

The last specification used is as follows:—"The whole of the cement shall be Portland cement of the very best quality, ground extremely fine, weighing not less than 112 lbs. to the striked bushel, and capable of maintaining a breaking weight of 250 lbs. per sq. in., seven days after being made in a brass mould, and immersed in water during the interval of seven days. The contractor shall at all times keep in store upon the works a supply of cement equal to at least fourteen days' requirements, and with each delivery of cement shall send to the clerk of works a memorandum of the number of bushels sent in and the name of the manufacturer."

The moulds used were of the form shown in drawing as No. 1, being $1\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in. in the centre, or breaking point, and $= 2\frac{1}{4}$ sq. in. A lever testing machine on the principle of the steel yard, and similar to the one I have brought here to-night, was used. I believe this machine is the only one in Liverpool, and I shall be glad to allow any one to use it, as I firmly believe the more common testing becomes, the better and more regular this cement will be made. The sale will increase the more its good qualities are known and appreciated.

I am glad to see that manufacturers are making the result of tests a marked feature in their circulars; but unless buyers have testing machines they will still be in the dark, as gauging small pats of cements and testing with the point of a knife is very fallacious.

At the Southern High Level Sewer (1859) every precaution was taken by Mr. Grant (the resident engineer) to have the apparatus fixed in testing houses on the works; access to these premises could only be obtained by the proper officers; ordinary workmen were soon trained to the work of gauging and testing. In six years more than 70,000 tons of Portland cement were used, and 15,000 tests made. It is a singular fact that the manufacturers strongly urged that only a standard of 300 lb., instead of 400 lbs., would in practice be found attainable; but luckily for the trade the higher standard was maintained, and before long without difficulty. At first a few parcels were rejected, but the same manufacturers persevered, and soon turned out a higher quality, and the tests show that in practice the standards fixed from time to time were, as a rule, far exceeded.

To the French and German engineers, in the first instance, are we indebted for initiating the process of tensile testing, which was followed by the engineers of the Metropolitan Board; and one of the most valuable contributions to the engineering world is the set of tables published by Mr. Grant.

The very marked increase in the manufacture of this cement is due to the increased confidence of engineers and contractors, who were aware of the precautionary measures adopted, and the very satisfactory increase in the standard of strength made during the progress of these important works.

The adoption of great care in the testing of cement is of little avail, unless the same rigid care is observed in selecting the sand to be used, and also in the proper amount of water.

Great mistakes are made in this neighborhood in using too fine sand; it is very common to hear of North Shore sand being specified to be used with cement. Cement is very frequently condemned when it is perfectly good, and this may be solely attributed to using improper sand. Not many months ago I had fault found with some Portland cement, which the architect prefaced his appreciation of by condemning before any of it was even gauged, and then he subsequently allowed the contractor to use the fine drift sand of Formby with it, showing his utter ignorance. A sample of the gauged stuff was brought to me, when I immediately saw what was the matter—it was quite soft and crumbly; I threw a portion into water, and it soon hardened, as shown in the sample submitted; the setting in water showed the cement was good, but it had been impoverished by the immense surface it had to cover.

The setting of cement is the chemical

action of crystallization. The cement must cover the whole surface of the contained sand; if the sand be too fine it has no chance of surrounding each particle; the coarser the sand the less surface there is to cover, and the cleaner it is, the more perfect the crystallization will be. If these facts were always borne steadily in mind we should hear less of failures, and the merchant and manufacturer would be spared many undeserved condemnations.

It is much to be deplored that it is so commonly intrusted to unskilled laborers to mix cement. Very frequently cement that has set is wetted up again, and for this, if any harm result, the quality of the cement is called in question. The marked difference in this respect to be seen on the Continent is due, I suppose, to technical education in contrast with the too general rule of thumb in this country. Proper mixing boards are still very rare; but on the Continent they are used as a rule, and the utmost care is taken in incorporating the sand and gravel with the cement before adding the water, as also in having the sand and gravel well washed.

To show the carelessness in this respect, a cement dealer in a neighboring town plastered his office inside with the best Portland cement as a sample. Shortly afterwards, treacley stains were seen in patches over the wall. On investigation it was found that small bits of coal had got into the sand; these stains were due to the coal. I have known several instances in which Minton's buff tiling has been ruined by sand in which peaty lumps have occurred; the chemical action of the cement on these has resulted in black stains in the tiles. A more recent instance—the proprietor for whom the work was done stipulated to find his own sand, and the tiler, being a young hand, laid the tiles, and peaty stains were the result.

In a discussion on Mr. Grant's first paper, Mr G. F. White, in calling attention to the weight of Portland cement, and the tendency of manufacturers, in making heavy cements, to combine an increased proportion of lime to enable them to push the calcination to a higher degree, to increase the density, said that it was at a risk of an imperfect amalgamation of the lime and clay, causing the fatal disintegration which many engineers have had to complain of. No doubt, for general builders' purposes, a Portland cement of a lighter gravity, say from 104 to 108 lbs. per bushel, would suit better, on account of its quick setting; but for engineering works of extensive character, and where time can be given for setting, the higher specific gravity must be both cheaper and more reliable. The very fact that the specified standard test was raised from 400 lbs. to 787.5 in something like 12 years, and that Mr. Grant's experience during the progress of these important works, as evidenced in the tables published by him, shows that, as a rule, the manufacturers were exceeding the specified strength considerably, and tells its own tale.

I will read you a few of the results I have gathered from Mr. Grant's valuable tables, and I trust, in the discussion that will follow, we may be able to add some of our local experience to the list. I hope, on some future occasion, to give you a more carefully prepared paper on this most important subject—this being a mere sketch. I must also leave another branch of this subject, that of "concrete construction."

When the nature and value of Portland cement is more and better understood we shall find the remarkable saving that may be made in the construction of cheap dwellings for the working-classes, and the easier adaptation of this material for sanitary appliances, such as ventilation, etc. As far as engineering is concerned, you may remember a fact stated a short time ago, that Mr. Bazalgette has, by the adoption of concrete backing for the granite walls of the Chelsea embankment, effected a saving of £25,000. In the construction of sewers a like economy is found. One sewer at Earl street, Deptford, is 7 ft. 1 in. in diameter, the substance of the upper part of the sewer being only 9 in. and the lower half only 4½ in. to 5 in. Our local engineers would tremble to attempt anything of the sort; but I trust in a few years to see Portland cement better understood in this town. There is no reason whatever that it should not be as extensively used here as it is in London and on the Continent generally. Several tables extracted from Mr. Grant's well-known work accompanied this paper. We have not thought it necessary to reproduce figures with which most of our readers are more or less familiar.

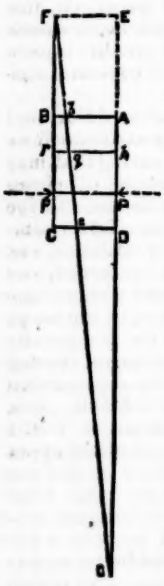
ON THE STRENGTH OF LONG STRUTS.

By WALTER R. BROWNE.

From "The Engineer."

Some weeks ago a correspondence appeared in "The Engineer," on the breaking strain of long struts of timber, in which the wide divergence of the different existing formulæ, both from each other and from the results of actual experiment, was forcibly pointed out. It is the object of the present paper to show that this divergence is inevitable—in fact that the question is one to which no exact formulæ can or ought to be applied.

When short pieces of any material are subjected to compression they yield by crushing or splitting equally in all directions. But with long pieces, such as timber struts, the case is different. They are found to give way by crippling on one side, and tearing on the opposite side, much as if they had been laid horizontally and broken by a vertical load. To this the name of cross-breaking has been given, and very justly; for it is clear, on reflection, that such a fracture can only be due to the fact that the line of resultant pressure does not pass through the centre of the section, as in ordinary crushing it is supposed to do. This deviation (caused by want of straightness, or other defect in the strut) must produce a bending moment on the section, which will break it exactly as in the case of ordinary transverse strain.



The effect may easily be examined theoretically. Let A B C D represent a very thin slice or element of the strut (supposed rectangular) when free from the action of any forces, and then let this element be compressed between two opposite forces, each equal to P, and acting, not through the centre of the section, but along some other line whose distance from the further edge A B $= p$. The effect must clearly be to shorten the element and at the same time to spring it into a curve; but as this curvature will be in our case exceedingly small we may safely neglect it, and with it also the resistance to flexure which depends upon it. The altered form of the element may then be represented by a trapezium such as A b c D, the pressure, and, therefore, the shortening of the fibre being greatest along C D and least along A B. The neutral line, where there is no compression, will be beyond A B, in some such position as E F. Take any fibre p q r and let A $p = y$. Then, if y be positive A E must be negative. Let A E $= -k$. Let b c and A D meet in O, and let A O $= R$. Let the length A B of the element be s, and the depth A D be d. Then, by Hooke's law, the strain on the fibre p q $r = \frac{r\,q}{p\,r} \times E$ (where E = modulus of elasticity). But by similar triangles

$$\frac{r\,q}{r\,F} = \frac{E\,F}{E\,O}, \text{ or } \frac{r\,q}{p\,r} = \frac{r\,F}{E\,O} = \frac{y-k}{\rho-k}.$$

Hence the strain on

$$p\,q\,r = \frac{y-k}{\rho-k} \times E.$$

The total strain on A B C D is found by integrating this expression between the limits O and d, and this total strain = P. Hence

$$P = \frac{sE}{\rho-k}\left(\frac{d^2}{2} - k\,d\right)$$

Again, the moment about A of the strain on

$$p\,q\,r = y + \frac{y-k}{\rho-k} \times E.$$

Integrating this from O to d, we get the whole moment of the strains on A B C D about A, and this moment = P p. Hence

$$P\,p = \frac{E}{\rho-k}\left(\frac{d^3}{3} - \frac{d^2\,k}{2}\right.$$

From these two equations we obtain

$$\frac{d^2}{2} - k\,d = \frac{1}{p}\left(\frac{d^3}{3} - \frac{d^2\,k}{2}\right)$$

whence

$$k = \frac{3\,p\,d - 2\,d^2}{6\,p - 3\,d}.$$

Now the value of the strain on $p\ q\ r$, as given above, is $\frac{y-k}{\rho-k} \times E$. And it is evident that the point where the strain is greatest is D, for which $y = d$. Hence the strain at D is given by $\frac{d-k}{\rho-k} \times E$. Substituting the value of k found above, and for $\rho - k$, the expression $\frac{E}{P}\left(\frac{d^2}{2} - k\,d\right)$ we have for the greatest strain at any point of the section the expression

$$\frac{(6\,p - 2\,d) \times P}{d^2} \times E.$$

If $p = \frac{d}{2}$, this becomes $\frac{P}{d} \times E$, which is the correct expression for the strain when it is rendered uniform by the pressure acting through the middle of the section. If p be greater than this, say

$$p = d\left(\frac{1}{2} + \frac{1}{n}\right)$$

then the expression is

$$\frac{P}{d} \times E \times \left(1 \times \frac{6.}{n}\right)$$

The form of this expression shows how rapidly the greatest strain increases as the line of pressure deviates from the middle of the section. Thus if the deviation be only 1-6th of the diameter, the strain on the outside of the strut is twice as great as it would be if there were no deviation.

It thus appears, that to determine the strength of long struts we must know the point at which the line of resultant pressure cuts any section. How can this possibly be discovered? It may vary to any extent, and mainly from two causes—want of straightness in the strut itself, and bad bedding at the ends, bringing the pressure on one side instead of in the middle.

We might assume that each of these is greater as the strut is longer. In that case p would be proportional to length^2; and greatest strain =

$$\frac{C\ (\text{length})^2 - 2\,d}{d^2} \times P\,E,$$

where C is some constant. Hence the strength would be proportional to

$$\frac{1}{C\left(\frac{\text{length}}{\text{depth}}\right)^2 - \frac{c}{\text{depth}}}.$$

With this we may compare Hodgkinson's formula, which makes the strength proportional to $\left(\frac{\text{depth}}{\text{length}}\right)^2$, or that of Mr. Gordon, which makes strength proportional to

$$\frac{1}{C\left(\frac{\text{length}}{\text{depth}}\right)^2 + 1.}$$

But it is clear that this assumption is far too vague to be trusted. Empirical formulæ are valuable where we are dealing with unknown laws of nature, because we are sure there is a rigid rule if we only knew it. But here variations are due, not to any natural laws, but to defects of material or workmanship, and these no formulæ can cover. The practical outcome seems to be that all rules are misleading, and that each strut must be judged on its own merits. Ascertain first how far it deviates from a straight line. If necessary, bevel off the ends at the concave side, so as to bring the pressure nearer to the other or convex side. Then making allowance for shakes, etc., you must form your own judgment how near the strut may be expected to come to the full strength of the material to resist crushing in the ordinary way, and this being a a known quantity the strength of the strut is given as nearly as seems likely to be attained in practice.

THE MANUFACTURE OF IRON AND STEEL RAILS.*

In order to get an idea as to the strength of steel rails, it will be well to review the tests to which iron rails have been subjected. In England, Mr. Ashcroft found that the best 80 lbs. rails broke under a 300 lbs. weight, falling 15 ft. In Germany the society of railway managers determined on and have long applied a test of 1,000 lbs. falling 10½ ft., as the standard which all first-class iron rails must reach. In this country no inspection nor test is applied, but tests made show that iron rails from our most reliable makers, break under a 6 ft. fall of a 1,500 lb. drop—an extreme test, most of

* A paper read before the American Institute of Mining Engineers, at Philadelphia, by J. B. Pearse, Esq.

those tested breaking under a far less test; some breaking with less than a 3 ft. fall of the same weight.

Everywhere where steel has been used, engineers have come to the conclusion that some test is required to show the regularity and strength of the product. As compared with iron, the tests which steel will stand are wonderful. After numerous experiments partially based on the experience of the rail mill at Graz, belonging to the Southern Railway of Austria, the society of German railway managers fixed upon a test of 2,000 lbs. falling 13½ ft. They found that this test represented the steel which suited their necessities, and also found that with steel of otherwise average purity, this test represented about ½ per cent. of carbon, and made it a rule to take no steel containing under three-tenths of a per cent. of carbon, because it was too soft. They expressed a hope that a harder steel could soon be made tough enough to stand the same test. In England, a test was adopted of 2,240 lbs., falling 15 to 17 ft. on the rail on heavy bearings. This test has been found satisfactory under heavy traffic on average road-beds, and has been invariably retained by English makers, and adopted by American makers. It is an expeditious practical way of ascertaining the qualities of the rail. Experiment in Germany and experience in England pointed out the test corresponding to the proper grade of steel, and the test adopted has been considered the most practical one. The jar from a moderate weight (2,240 lbs.), falling from a great height, is more sudden than that imparted by a heavy weight falling a small distance, and better adapted to exhibit the toughness of the rail. This latter is the object had in view in all tests, as it would take far too long a time to determine the quality of rails by a treatment approximately similar to that received in the track. An objection of some force has been urged against the English method of obtaining test pieces. They take one rail from each day's rolling, to indicate the quality of the rest. In this way their test becomes a matter of chance, and nothing they have yet done removed this character. Our American practice has been to test every charge, thereby insuring beyond doubt the quality of the rails.

After a short experience with steel rails it was found that their homogeneity is their distinguishing characteristic; but they unite entire homogeneity with considerable hardness as compared with iron. There are no layers to peel off, no welds to open out, the ends of the rails do not broom out as iron rails do, and the head wears uniformly along its whole length. Not only is the single rail entirely homogeneous, but all the rails made from a single charge have exactly the same qualities. Many experiments on the steel at Seraing in Belgium, in Austria, and in this country, before and after its conversion into rails, show this to be a fact.

But the hardness is a most important point as regards wear. Some first rate English rails have been found too soft for roads with heavy traffic. Therefore, a rail is wanted which will be hard enough to stand abrasion and wear, but strong enough to stand all the strains to which it is liable. The railroad engineer's idea of hardness is that quality which imparts durability without brittleness. Hardness is sometimes erroneously associated with brittleness because some hard bodies are brittle, but in steel brittleness arises from causes entirely different from those which produce hardness. The steel maker's idea of hardness is a composite one — one that results from considering the effects of physical structure or grain of the steel, and the effects of carbon, phosphorus, and manganese. The effects produced by the presence of these elements far exceed any brought about by change of physical structure. Phosphorus and manganese occasion brittleness, while carbon in excess is seldom present, as the processes through which the rail passes have a constant tendency to reduce it. The state in which carbon is present in the rail is, however, remarkably influenced by mechanical treatment and the resulting physical structure. Those modes of reduction which work quickly and forcibly, exert a strong influence to retain the carbon in a combined state, while the slower methods, on the contrary, permit some of the carbon to separate as graphite. These facts have been observed by Gruner and Caron, and have been corroborated in Austrian practice, as the following analyses of steel will show:

(*a*) Steel made for heads of steel rails

at Graz, and rolled into shape without hammering:

Combined carbon	0.38
Graphite	0.65
Silicium	0.05
Manganese	0.07
Sulphur	0.05
Copper	0.08
Iron	98.57
	99.85

(*b*) Steel made at Neuberg and hammered into shape:

Combined carbon	0.234
Graphite	none
Silicium	0.033
Phosphorus	0.044
Sulphur	traces
Manganese	0.139
Copper	0.105
Iron	99.445
	100.00

Both these steels were soft Bessemer steel, and from observation I made at the two works on the respective quality of their metal, I see no reason to doubt their correctness. A remarkable point in the matter is that their iron at Neuberg was much more graphitic than that used at Graz. At Neuberg they tapped direct from the blast furnace, and their "blows" averaged about 30 min., some running up to 50 min. At Graz they remelted their iron in an air furnace, and their "blows" were much shorter. The iron each works used was then of substantially the same character, made by charcoal from spathic ore. Neuberg made its own iron, while Graz bought its iron largely from Mariazell and Eisenerz, furnaces not far from Neuberg.

Now, at the Pennsylvania Steel Works we have a quite graphitic mixture, for conversion, but we find scarcely any graphite at all in the rails—in fact none. Out of many tests we have only one, an apparently abnormal one, in which the graphite amounted to 0.08 per cent., it being generally present in too small quantities to be estimated.

Speaking within the limits of steel manufacture, it is safe to say that brittleness has nothing to do with the mechanical treatment, yet by this treatment the state of the carbon may be controlled and the specific gravity and consequent density of the steel increased. Rails are brittle when too cold-short from the presence of phosphorus and manganese. The proper proportion of the former forms the most delicate point in steel making, and must always be kept within safe limits. No good steel rail has ever yet been made with more than 1-5th of 1 per cent. of phosphorus, and half that is considered too much by Bessemer. In regard to manganese, our experience is not yet fully ripe. Its action, however, is far less dangerous than that of phosphorus, and in small quantities is beneficial.

We have thus a definite idea of the important qualities of steel rails and the proper tests to show their uniformity. The tests made on the steel preclude possibility of brittle steel being used, and it is evident that those methods of reduction which unite the greatest hardness with the necessary strength are to be preferred. In general terms, a steel rail is wanted to last a lifetime, and be strong enough to stand all accidents of wear.

Rail-making begins with the Bessemer ingot. This is a block of highly crystalline metal, the tensile strength of which is low, and which contains some blow-holes or bubbles formed by the carbonic oxide retained by the liquid steel. The inner surface of these bubbles is generally oxidized, and they are apt to be more numerous near the surface of the ingot.

The first steel rails made 10 years ago were treated like cast steel. Until 1863 they were made from ingots 7 to 8 in. sq. and 4½ ft. long in 4 heats. In the first 2 heats the ingot was hammered down to size, one end at a time, and swaged in dies to the shape of the first pass of the rolls. Then the bloom, by this time 8 ft. long, was rolled in 2 heats through 12 passes into a finished rail.

This process was excessively crude, wasting everything a steel-maker cares to save, and as the rails were found deficient and their weak points tested, it was found that the small size of the ingots and the little work done on them caused a great number of imperfect rails and a very poor quality in the steel. At this time the expressions of want of confidence in Bessemer steel took shape. We have now, however, surmounted all difficulties, and produced a reliable uniform quality of steel in enormous quantities, considered in the light of former capabilities of production. We now use very large ingots, which necessitate thrice the work formerly applied. In 1867 the ingots were raised in England to 10 in. sq., and in 1870 to

12 in. sq., which is the size in general use. In America we have had exactly the English experience with small ingots, the efforts to use them to advantage having entirely failed.

Seeing, then, that large ingots weighing ¾ of a ton, and making 2 rails, have been found necessary, it has become a question as to what mode of working them up gives the best results. I think that hammering furnishes the preferable product, and my present experience goes to justify the opinion. Rolling is preferred by some makers because it is thought cheaper, but I think the better wear of a hammered rail is a strong point in its favor. Rolled rails are generally softer than hammered rails, for the reason I have given—namely, because their carbon is apt to be partially separated as graphite, and their density is less.

There have been, in the history of iron metallurgy, two noted contests between rolling and hammering, in one of which the hammer came off victorious, in the other the rolls. I refer to the manufacture of hammered iron and to that of armor plates. Hammered iron is a necessity for smith work, and the qualities imparted to it by continued piling and hammering are wonderful as compared with ordinary iron. The reputation of the Low-Moor and Yorkshire iron tyres and plates is world-wide, and the steel tyre had in the Low-Moor tyre for some time a formidable competitor. In this case the benefits are produced by a better texture of the iron and greater ductility developed by the work done. The cinder is thoroughly expelled in the blooming and first piling, and may be left out of the question. In the other case the object was to get as soft and wax-like an armor plate as was consistent with the strength necessary to resist the impact of the shot. As the work done by the shot generally used represents in foot-pounds the effect of 1 (gross) ton falling 1¼ miles, it will readily be acknowledged that there is little similarity between the case of an armor plate and a steel rail, which has to stand a ton weight falling only 17 ft.

In my own experiments on the effects of the two processes, I compared ingots of the same steel with an average area of respectively about 75 and 110 sq. in., average section, as they were the only moulds I had at the time to compare. I found that the rails made of blooms, hammered from the ingots of the latter section, stood over 100 per cent. more than the rails made direct from the ingot. The bloom was hammered to the size of the ingot, and each rolled in two heats, one of them a wash heat, into the same kind of rails. I tested in this way 31 different charges. Weight used was 2,000 lbs.; bearings, 2 ft. apart. The rails from ingots stood 21½ ft. fall of this weight, showing $1_{\frac{6}{10}}$ in. deflection without breaking. The rails from the blooms stood a 43 ft. fall of the same weight without breaking, and showed a deflection of $3_{\frac{2}{10}}$ in. This leaves a surplus of 50 per cent. in favor of the hammered rail, deducting 50 per cent. for amount due to difference of area of ingots. To show the connection on a manufacturing scale, of these tests with the actual result, I would remark that we made 13,285 rails out of the ingots of 75 sq. in. average area. Of these there were rejected by the railroad, for insufficient strength after delivery, 178 rails, or 1⅓ per cent. Of the larger ingots we had made up to the fall of 1870—34,320 rails, and had rejected for all causes, after delivery, only 18 rails, or $\frac{1}{20}$ of 1 per cent., or a quantity only $\frac{1}{240}$ as large as before.

We therefore continued to hammer, but now use an average section of 150 sq. in.; doing ¾ the work under the hammer, and only ¼ in the rolls. Our rails thus produced stand a ton weight falling 17½ ft., and leave an ample margin of reserved strength. We have had recent tests, in which the rail stood what was equivalent to a ton weight falling 70 ft., without breaking, but have not yet got up to the armor plate standard of a mile and a half. Out of a lot of 1,200 tons of 58 and 60 lb. rails, not a single rail, out of the 439 tests given, broke under a ton weight falling 16½ ft. We have since had many similar ser es.

The bubbles in the ingots give some trouble in the subsequent working, sometimes occasioning cracks in the ingot requiring to be chipped out. This we do, as we hammer the ingot down, without hindering the hammer in its work. Rolls are apt to laminate these bubbles instead of forcibly compressing them, like the hammer, and it sometimes happens that the bubble breaks out on the surface of the bloom and causes a long streak where

the metal is not sound. These streaks are especially noticeable in the head of the rail. In order to obviate the cracks resulting from these blow-holes, a hammer must be associated with the rolls to chip out bad places; and this renders the rolling process more complicated than it would appear at first sight. I do not see why it is not simpler to do all the work under one tool, viz., the hammer.

The objections to hammering on the score of cutting sharply into the metal, are not, in my opinion, of weight, as our experience agrees with the English, that you can hardly have too heavy a hammer for steel. We can strike 2 full blows of a 12-ton hammer on the same place without deforming or injuring the bloom in any way, or making a mark on it deeper than $\frac{3}{4}$ in. each time. As showing what steel will stand, I will say that I have seen, in Vienna, Haswell's hydraulic press reducing ingots from 10 in. thick to 2 in., at one squeeze, without injuring the steel, which was from Neuberg. It is thus surely idle to talk of a hammer as injuring steel in any way. The stroke of a heavy hammer works uniformly through the bloom, drawing the interior as much as the surface. We want to make a hard and tenacious bloom, and the concentrated blow of a heavy hammer is well adapted to that end. We lose practically nothing in ductility as compared with the rolls, and have ample room within the limits of our strength. The chemical composition controls the brittleness of our rails, and as long as we keep that right we can make a comparatively hard rail, well adapted to wear.

In regard to the amount produced by the two methods in the same time, the hammer compares very favorably with the rolls. A blooming mill turns out about 55 tons of blooms a day from ingots. We do as much as that daily under a 12-ton hammer, and have done much more than that for a considerable time, so that the relative capacity of the two is hardly decided as yet. In 5 to 6 min. we can hammer down, chip, and cut in two, and carry away a large ingot reducing it to $\frac{1}{4}$ its former size; and in 35 to 40 min. do the w. ole work of getting a heat of 5 ingots hammered complete into finished rail blooms requiring no subsequent hand-chipping. For 3 months this hammer did an average of about 70 tons of rail blooms per day, turning them out sound and well chipped.

As a matter of interest, it may be well to refer to the fact that at Neuberg, in Styria, they use a 19-ton hammer on steel, and, according to published statements, produce under it in a week only 65 tons out of 2 furnaces in $11\frac{1}{2}$ turns. They hope, by using 4 furnaces, to get up to 130 tons a week. It shows well the spirit of American work to compare our product with this. We do now over 3 times as much as they hope to do, and do it under a hammer of under $\frac{2}{3}$ the weight. The weight of ingots is about the same.

I have explained above my reasons for preferring hammered rails, all derived from experience capable of easy verification. In practice we have found, as far as we could compare hammered with rolled rails, that the former stand the treatment they have to suffer better than the rolled rails. From experience with rails of different making, rolled and hammered from ingots of the same size, I am enabled to say that the hammered ones have far less rejections on all accounts than the rolled ones, and that their strength against sudden jar is greater.

I believe, therefore, that the hammered rails are superior to the rolled in very important characteristics. I do not deny that rolling may be improved so as to equal a hammered rail. That is not impossible or improbable. It has not done it yet in my opinion, but when it does I shall be most happy to change my opinion.

In order to show the relative endurance of iron and steel rails, I would like to mention a case that may be regarded as furnishing an American experience of steel rails, equalling that had on the English railroads, and especially on the London and Northwestern. The Philadelphia, Wilmington, and Baltimore Railway laid in their yard in Philadelphia, steel rails on one side of the track and iron rails on the other. The steel rails were hammered rails, and were, with the iron, laid in 1864. The steel rails wore out some 17 sets of the iron rails, and then the Company stopped the experiment, laying steel on both sides.

On a curve of 525 ft. radius, steel rails have lasted intact since 1865, and are as perfect as when laid, where iron rails had before lasted only from 3 to 6 months.

None of the rails of the Pennsylvania Street Company, nor of any other company in this country, have ever been worn out by traffic or shifting work, so that I can, after a five years' experience of American makes, have reason to believe they will last at least a generation, under the hardest service.

PREVENTION OF BOILER INCRUSTATION.

From "The Mechanics' Magazine."

At the Vienna South Station important experiments are being carried on with feed-water according to M. Bérenger's suggestion. The process consists in softening the water by a solution of lime, and forcing the liquid, which holds the generated precipitate in suspension, through a particular kind of filter. There is no necessity to wait for the settling of the precipitate. From 10 to 15 filters, each of 0.1 cubic metre in capacity, soften about 410 cubic metres of water per day. In 10,000 parts of water, according to analysis, there are contained

	Before softening.	After softening.
Common salt	0.8029	0.8257
Chloride of magnesium	0.2986	0.2892
Gypsum	1.9398	1.6796
Carbonate of lime	1.8830	0.0292
Carbonate of magnesia	1.4729	0.0178
Silicic acid	0.0715	0.0580
Organic substances	1.9853	1.4370
	8.4540	4.3345

Protracted boiling produced in 10,000 parts of unsoftened water a sediment of 3.3510 parts, consisting of

Carbonate of lime	2.3420 parts.
Carbonate of magnesia	1.0090 "
	3.3510 "

In 10,000 parts of softened water, a sediment of 0.0305 parts was found, consisting of

Carbonate of lime	0.0265
Carbonate of magnesia	0.0040
	0.0305 parts.

The hardness of the unsoftened water, tested by soap solution, was 26 deg.; that of the softened water 8.5 deg. Before being softened, the feed-water produced at times magnificent specimens of incrustation. Some of these were analyzed. They were found to consist of layers of several inches in thickness, having a bluish-gray color. These products contained in 100 parts the following:—

Carbonate of lime	73.87 per cent.
Carbonate of magnesia	19.40 "
Gypsum	2.29 "
Oxide of iron and alumina	3.07 "
Silicic acid and sand	0.83 "
Water and organic substances	10.93 "
	100.39 "

The sediment produced by softened water, on the other hand, consisted of a loose yellow powder, which after 6 months' use of the boiler was taken out. One hundred parts of this muddy substance contained:—

Gypsum	70.60 per cent.
Organic substances and water	18.23 "
Carbonate of magnesia	1.57 "
Carbonate of lime	1.41 "
Chloride of calcium	0.07 "
Silicate of lime	0.65 "
Ferric oxide and alumina	1.52 "
	100.05 "

The precipitate formed by addition of lime water is retained in the Bérenger filter. One hundred parts of this precipitate contain:—

Carbonate of lime	69.71 per cent.
Carbonate of magnesia	10.96 "
Gypsum	7.92 "
Silicate of lime	0.63 "
Ferric oxide and alumina	3.46 "
Water and organic matter	5.57 "

From the above it is plain that, by this process of softening, the carbonates of lime and magnesia are almost entirely removed, and also part of the gypsum. The quantity of silicic acid and organic matter is also considerably diminished. If there be a large quantity of gypsum in the water, it is best to precipitate that by the carbonates of lime and magnesia, and part of the gypsum dissolved in the water, saturated with carbonic acid. By a subsequent addition of soda the remainder of the gypsum and muriate of magnesia, as well as occasional traces of chloride of calcium, are changed into carbonates of alkalic earths.

REPORTS OF ENGINEERS' SOCIETIES.

THE POLYTECHNIC CLUB.—At a recent meeting of the Polytechnic, the following pertinent discussion was offered on the "Ellis Bi-Sulphide of Carbon Engine." We make the extract from the columns of "The Engineering and Mining Journal."

DR. VAN DER WEYDE.—Mr. Ellis, of Boston, has lately constructed a Bi-Sulphide of Carbon Engine, using the waste steam from the engine to heat the bi-sulphide of carbon, and work another piston attached to the same engine. There have been two objections made to this, which I wish to answer. One objection is that we might just as well have 2 steam cylinders, making a compound engine, the steam from a high-pressure engine working a low-pressure engine. The other objection is, that if we are to use the bi-sulphide of carbon, we do not need the steam, and I will reply to this objection first. Volatile substances require very little heat to convert them into vapor. Water requires a temperature of 212 deg. to vaporize at atmospheric pressure, and 966 units of heat become latent. But ether will vaporize at 96 deg., and only 165 units of heat are required. That is an immense saving of fuel. On that idea, some 15 years ago, an ether engine was built at the Novelty Works, New York. But practical difficulties came up. First, it was difficult to get the joints tight; and when it leaked it took fire, and alarmed every one. Another difficulty was, that the latent heat was so much by weight, and the vapor of ether is nearly seven times as heavy as steam. It is a curious property of vapors, that whatever the temperature of vaporization, and whatever amount of heat becomes latent, in units, the amount of latent heat in a cubic foot of vapor, is always the same; and as engines are driven, not by the weight of the vapor but by its volume, that takes away all the supposed advantage of volatile fluids with regard to their latent heat.

The first objection was, that we might as well use the team from a high-pressure engine to drive a low-pressure engine. The simple answer to that is, that all the pressure you get from the waste steam becomes back pressure on the first engine, and you have all the machinery and friction for nothing. But if you pass your waste steam freely through tubes which heat bi-sulphides of carbon, there is no back pressure, and the pressure you obtain from the vaporization of the bi-sulphide of carbon, is a clear gain. Fairbank & Dunkin in England founded a method of judging of the performance of steam engines, by measuring the water of condensation, as it was done in the recent trial at the American Institute Fair. In the best steam engine, the water of condensation is warmed somewhat, and that amount of heat is lost. Now let us see what is the pressure with different vapors:

Ether.	Bi-Sulphide of Carbon.	Water.	Pressure.
95 dgs.	110 dgs.	212 dgs.	1 atmosphere.
115 "	130 "	250 "	2 "
125 "	140 "	276 "	3 "
133 "	148 "	291 "	4 "

Now if we take the steam at 212 deg., you see that it will produce a pressure of much more than 4 atmospheres in the bi-sulphide of carbon. It is asserted that by this engine, a nearer approach has been made to theoretic perfection, in the power produced, than ever before.

Another point. In heating water from 212 deg. to about 248 deg., you double the pressure; so that at least 2 deg. are necessary for every pound of additional pressure. But if you heat it to 500 deg., where the pressure is 50 atmospheres, then 15 deg. will produce 15 atmospheres more pressure, or a whole atmosphere for every degree. Here we have to keep the water at 500 deg. and upwards; but there are other liquids that do not require that temperature. Take the liquefied carbonic acid gas, which boils at 148 below zero. Heat it to 100 deg. below zero, and you have 2 atmospheres pressure; an additional atmosphere for about 48 deg. But heat it to 32 deg. and you have 32 atmospheres; and at 50 deg. you have 50 atmospheres, making a whole atmosphere for every degree. It is only necessary, then, to maintain the ordinary atmospheric temperatures, and in the summer all you have to do is to heat with the atmospheric temperature, and to cool with ice. Your engine will require no coal. But you will have this drawback, that melting ice only consumes 140 units of heat, whereas the combustion of coal gives out 14,000 units of heat. For every pound of coal, therefore, you will want 100 lbs. of ice; and ice is not so easy to keep, especially in the summer, as coal. Another difficulty is that the boiler must be strong enough to stand 50 to 65 atmospheres of pressure. Of course, this whole plan is intensely absurd; but as Cicero said that no theory was so absurd that no man would adopt it, so in mechanics, no plan is so absurd that no one will try to carry it out; and there is a young gentleman now endeavoring to carry out this plan. He will have a back pressure of 50 atmospheres on his piston—a very respectable back pressure.

INSTITUTE OF MECHANICAL ENGINEERS.—At the meeting of the Institution of Mechanical Engineers held at Birmingham on the 25th ult., a paper was read "On the Strength and Proportions of Riveted Joints," with the results of some recent experiments, by Mr. Walter Browne, of Bristol. In this paper four different modes of fracture possible in riveted joints were described, consisting in—shearing of the rivet—crippling of the plate, or elongation of the rivet hole in the line of strain—fracture of the metal between the rivet hole and the edge of the plate, in the line of strain—or tearing of the plate along the line of the rivet hole, at right angles to the line of strain. From the consideration that a perfect joint would be one offering equal resistance to each of these modes of fracture, the proper proportions were deduced for the various descriptions of riveted joints, with the aid of data furnished by different experiments previously recorded, and by a series of experiments recently made for the purpose by the writer. The proportions thus obtained for single-riveted lap-joints are that the diameter of the rivets should be twice the thickness of plate, and the pitch of the rivets and the width of the lap should each be three times the diameter of the rivets. For double-riveted lap-joints, the diameter of the rivets being again double the thickness of plate, the pitch should be 4½ diameters, and the

width of the lap should be 5¼ diameters in chain riveting and 6 diameters in zigzag riveting. For butt-joints with a single cover-strip the proportions are the same as for lap-joints; and with double cover-strips, the thickness of each strip being only half that of the plates, the diameter of the rivets should be 1¼ times the thickness of plate, and in single-riveted joints the pitch should be 3¼ diameters and the width of the cover-strips 6 diameters; in double-rivetting, the pitch should be 5 diameters, and the width of the cover-strips 11 diameters in chain riveting and 12 diameters in zigzag rivetting.

A calculation of the proportionate strength of these different joints, as compared with the strength of the solid plates themselves, shows that but little advantage is obtained by the employment of butt joints in place of lap-joints, so far as mere strength of joint is concerned; and even in the best instance the strength of a double-riveted butt-joint with 2 cover-strips and drilled holes is less than ⅞ of that of the plate, while in common single riveted lap-joints with punched rivet holes the strength is little more than half that of the plate, thus involving practically a serious waste of material. In the case of cylindrical boilers, constructed with the ordinary longitudinal and transverse joints of the plates, the strain produced upon the longitudinal joints by the internal pressure of steam is double that upon the transverse circular joints; and two modes of remedying this inequality in the strength of the joints have been adopted. The first consists in arranging the joints diagonally, in spiral lines round the boiler, whereby the effective strength of the joints and of the boiler is increased in the ratio of 4 to 5.

In the other plan the boiler plates are rolled with thickened edges along the longitudinal joints, by which means and by double-riveting the longitudinal joints, the strength of the joints is brought up very nearly to that of the solid plates themselves without the necessity either of butt-jointing or of drilling the rivet holes; the thickened edges have also the advantage of obviating the ordinary corrosion occurring at the joints, which is so fruitful a source of boiler explosions. The importance of the subject investigated in the paper is sufficiently shown by the serious consequences which have arisen from defective construction of joints, both in boiler work and in iron shipbuilding.

AMERICAN INSTITUTE OF MINING ENGINEERS.—*Proceedings of the Fourth Quarterly Meeting, Concluded.*—The Institute met according to programme, on Wednesday evening, the 21st, for its second session, the day having been spent by the members and associates in visits to various points of interest. The large magic lantern of the Franklin Institute was kindly lent for this occasion.

Mr. Benjamin S. Lyman exhibited upon the screen an excellent view of the famous iron column at Delhi, from a photograph which he had brought with him from India. This column has been recently described in the London "Engineer." Mr. Lyman having frequently seen it, his statements with regard to it were eagerly listened to by the metallurgists present. He believed the column to be of wrought iron, and suggested that the expression "mixed metal," in the report of the Archæological Surveyor to the Government of India, might refer (if it means anything) to some apparent impurity or imperfect reduction of the iron. The column is 22 ft. high above ground, 16.4 in. in diameter at the ground, and 12.05 in. at the top. It is said to extend at least 26 ft. below the surface of the ground. The inscription upon it indicates by its Sanscrit characters an antiquity of 1,500 years or more. The popular legend concerning it, that it was driven into the earth by the last ruler of the Hindu dynasty, at the suggestion of his soothsayers, to pierce the serpent who lies coiled beneath the world, is not corroborated by the inscription, which commemorates the glory of one Dhara, of whom nobody now knows anything. It is noteworthy that the popular legend expresses no sense of anything unusual in the material or mode of manufacture.

After this, a paper was read by Dr. Thomas Downe upon a new testing machine for metals.

Next followed a paper by Mr. A. L. Holley on Rolling Mill Machinery.

The first paper of the third day's session was prepared by the President, but was read in his absence by Prof. Maynard. The subject was the Anthracite Furnaces of the Lehigh Valley.

U. S. Commissioner Raymond read a paper on a new electro-magnetic separator, the invention of Mr. Balch, of Baltimore.

The next paper was by Mr. S. H. Daddow on Pillars of Coal.

A paper by Mr. Loiseau on the "Utilization of Coal Dust as Fuel," was next read. This was followed by a paper by Maj. T. B. Brooks on "The Methods of Extraction employed in the Iron Mines of Lake Superior."

A paper by Prof. Thomas Egleston on the "Utilization of Furnace Slags" closed the morning session.

The papers of the evening were as follows:

"On Exploring for Iron Ore," by Maj. T. B. Brooks.

"Blast Furnace Fuel," by Mr. S. H. Daddow.

"Surveying in Geological Work," by Mr. B. S. Lyman.

The resignation of the President of the Institute created a vacancy, which was filled by the election of R. W. Raymond, U. S. Commissioner of Mines, and Vice-President of the Institute. Mr. R. P. Rothwell was thereupon made Vice-President to fill the new vacancy.

At the close of the discussion, the President briefly congratulated the Institute upon the unmistakable success of its first four quarterly meetings. The character of the papers presented, the vigor and good temper of the discussions, and the great social enjoyment and professional profit which all all have derived from the meetings, have been so many pledges of the future prosperity of the Institute.

No one has been urged to join the Institute; its doors are open to the profession and to the public interested in its objects; but it is not a beggar for members or associates. Assured in its vitality and progress, it is assured also in the expectation that the mining engineers and metallurgists of the country will gather around it, not for its sake, but for their own.

The Institute then adjourned, to meet again in May, at such place as shall be announced by the Council.

IRON AND STEEL NOTES.

TESTS OF DANK'S ROTARY PUDDLER AT THE AMERICAN IRON WORKS.—We last week gave extracts from the report of the English Commission sent to this country to examine the workings of this furnace. The following extract from "Statement No. 11" will interest our readers:

Jones, Laughlin & Co., Pitts. Mr. Jones very kindly had the furnace put in order and worked a few heats specially for us, from American iron of various classes. The results obtained were:

1st Charge—"Douglas iron" gray pig, from ¾ Lake Superior, ¼ Lake Champlain ore and raw coal; pig, 520 lbs.; bloom made under hammer, 520 lbs.. 210 lbs. of this charged into heating furnace gave 196 lbs. merchant bar.

2d Charge—"Eliza iron" mottled and close gray, made from all Lake Superior ore with coke. Charge put in at 10.45, brought out at 11.55. This ball was too hot in the centre, and cold on the outside, and went to pieces under hammer.

3d Charge—"Douglas iron." Mr. J. A. Jones caused this heat to be worked in a slightly different manner, whereby the quality was much improved, but the yield was not so good—515 lbs. pig gave 433 lbs. hammered blooms. The iron from this heat stood the most severe hot and cold tests admirably.

From the books of the Company we extracted the following results of charges worked in the rotary furnace:

RESULTS.	Charges.	Pig Charged.	Hammered Bloom.	Iron Turnings.	Ore.
April 8	6	4,200	4,305	115	600
" 21	6	4,220	4,270	310	715
" 22	4	2,825	2,792	135	742
" 24	5	3,540	3,771	*	485
" 25	5	3,600	3,722	160	800
" 26	6	4,240	4,127	235	762
" 27	5	3,585	3,575	240	910
" 28	5	3,560	3,698	230	915
" 29	5	3,567	3,809	240	705
May 1	4	2,850	3,010	140	980
"	2	3,550	3,611	135	718
	56	39,737	40,690	1,940	8,332

* No turnings.

Yield per ton hammered blooms.

Pig iron ton of blooms.			Iron turnings.		Iron ore.		
cwts.	qrs.	lbs.	qrs.	lbs.	cwts.	qrs.	lbs.
19	2	3	3	22	4	0	9

—*Chichago Railway Review.*

THE ROLLING MILLS OF PITTSBURGH.—The first attempt at making bar iron in Pittsburgh occurred in 1813, particularly for the hardware trade. It was operated with indifferent success until 1845, when it was suspended. A second mill, put in operation in 1819, operated until 1829, when it was discontinued. In 1825 three mills were put in motion, and from that time until now, 26 have been erected, making 29, all except one, still in operation. One of these is now able to do as much work in one week as half a dozen were at first able to do in 3 months. The machinery employed at the close of 1871 was as follows:

Rolling or puddling furnaces	720
Heating furnaces	180
Nail, tack, and spike machines	542
Railroad spike machines	19
Steam hammers	85
Eight inch roll trains	48
Nine inch roll trains	1
Ten inch roll trains	19
Twelve inch roll trains	9
Sixteen inch roll trains	29
Eighteen inch roll trains	33
Twenty inch roll trains	47
Twenty-six inch roll trains	1
Twenty-eight inch roll trains	1
Thirty inch roll trains	1

A number of these trains are three-high, of the Louth patent. The manufacture of rolls is a large part of the iron business of Pittsburgh, one firm alone having made, during 1871, 600 rolls.

The largest of these are employed in the manufacture of plate iron for naval use, some 1½ in. thick, 4 ft. wide, and 15 ft. long. But the great bulk of the iron turned out is merchant bar and sheet, and sheet steel for boilers and saws, which finds a market in every State in the Union, the present aggregate value of which is $24,000,000.—*Chichago Railway Review.*

RAILWAY NOTES.

FRACTURE OF RAILWAY AXLES. From the official reports of the "Verein Deutscher Eisenbahn Verwaltungen," it appears that during the year 1870, on 22 lines belonging to the Association, 132 axles of locomotives, tenders and carriages, were broken. In comparison with the previous year, in which the fractures amounted to 163, those figures show an improvement. There is a decrease of 19.3 per cent. on the service, which, considering the extraordinary demands occasioned by the Franco-German war, and the increase of rolling stock in Austria, appears considerable. The fractures either occurred or were remarked in the months of

December, January, February,	in 39	cases
March to May (inclusive),	in 30	"
June to August "	in 25	"
September to November "	in 38	"

The influence of the cold season, despite much that has recently been said to the contrary, is distinctly marked; from March till August 55 only, and during the other months, 77 axles broke. The average run of the axles broken in 1870 was as follows:

Locomotives	11	years	4	months	13 days
Tenders	13	"	4	"	20 "
Carriages	11	"	11	"	13 "
Average	12	"	2	"	29 "

The average mileages of the axles were in the case of

Locomotives	34,241.7	miles (German)
Tenders	31,494.5	" "
Carriages	24,040.1	" "
Average	27,631.1	" "

The maximum mileage attained was 69,000 miles. Since the last preceding inspection, they had run on the average as follows:

One locomotive axle	2110 7 miles
One tender axle	1795.8 "
One carriage axle	1426.6 "
Average	1677.6 "

Similarly to the results of the preceding year, the broken tender axles show a higher figure of run than the carriage axles; the explanation, probably, is to be found in the fact that the tender exles are more often inspected and sorted out. The mileage of puddled and cast-steel axles is, as in former years, less than that of wrought-iron ones, showing room for improvement. As a rule, where a fracture has commenced in a steel axle, that axle is sooner doomed than would be the case with a wrought-iron one. As far as could be ascertained, 38 per cent. of the fractures occurred at fall speed, 41 per cent. at medium speed, and 20 per cent. at rest. It is remarkable that the full speed shows a lower figure than the medium speed.—*Railway Times.*

GRAND RAILWAY ENTERPRISE. The Peruvian Government proposes a railroad 14,000 ft. above the water. It will connect different parts of the country by railway and steamboats, the former going over the main ridge and valleys of the Andes at an elevation of 14,000 ft. above the level of the sea, or 7,000 ft. higher than the highest point of the Sierra Nevada, crossed by the Central Pacific Railroad. This elevation is within 1,000 ft. of perpetual snow. Edward H. Spaulding, of Bloomfield, New Jersey, for 4 years Assistant Engineer on the Montclair Railway, has sailed for Peru, in company with some of our best American engineers, who have been selected to accomplish this difficult undertaking. The railway goes from Peru to Arequipa, 40 miles; thence to Puno, on Lake Titicaca, 800 ft. above tide water. Lake Titicaca is partly in Bolivia and partly in Peru, and is one of the principal sources of the Amazon, which is navigable for nearly 4,000 miles. The combined railway and steamboat communication will cross the continent at its widest point. Mr. Meigs, the contractor, has had contracts in that country amounting to over one hundred millions of dollars. American styles of cars and rolling stock will be introduced on that railway.

RAILWAYS OF THE WORLD.—The following estimates of the total length and cost of railways in the world, appear in the last number of the "Rev. Ind.:"

	Kilometers.	Francs.
Europe	97,660	41,261,950,000
America	89,959	12,163,450,000
Asia	7,158	2,073,915,000
Africa	932	274,685,000
Australia and Polynesia	1,974	501,005,000
	189,691	56,274,500,000

or a total of 119,871 miles and nearly 2,251 millions sterling. The average cost per mile, resulting from the foregoing, is £19,097, varying in the different continents as follows: Europe, £36, 863; America, £9,421; Asia, £18, 397; Africa, £18,718; and Australia, £12,922. The length of railways in operation in France is stated at 11,185 miles, about 10 per cent. of the grand total, and 18 per cent. of the European net work.

ENGINEERING STRUCTURES.

NEW RAILWAY BRIDGE AT ALBANY.—The new railway bridge over the Hudson at Albany, N. Y., begun in June, 1870, has lately been completed. The main bridge is 1,525 ft. long from Quay street to Van Rensselaer island, and the whole length, including approaches, 2,250 ft. It is 30 ft. in the clear above low water mark of 1857. There are two bridges above Van Rensselaer creek (the first comprising three spans 62 ft. 6 in. each) one connecting with the New York and Boston railways, and the other for Troy local trains. The portion of the bridge across the basin descends 3 ft. from the pier to Quay street. The trusses in the superstructure are 26 ft. apart. All the tension bars of the bridge are of double refined iron, and it is calculated that the brige will stand a load of 6,000 lbs. per lineal ft., exclusive of the weight of the structure, the strain of which will not exceed one sixth of the breaking weight. The draw weighs 350 tons, and is to be worked by a ten horse power engine placed beneath the roadway. Clark, Reeves & Co., of the Phœnixville Bridge Works, Phœnixville, Pa., were the contractors for the superstructure.

HOUSATONIC RIVER BRIDGE.—The new iron bridge over the Housatonic river at Stratford, Conn., on the New York and New Haven Railroad, is completed. This bridge is one of the handsomest in the State. It was commenced in March, 1871, and has been pushed, in spite of the cold weather of the early winter, to completion in a wonderfully brief time. The bridge is 1,091 ft. long, 27 ft. wide, with two tracks, and the height of the iron work is 24 ft. It has five spans, three on the east side of the draw and two on the west, and the draw is 206 ft. long. Five piers and two abutments of solid masonry support the iron work of the spans; and the height of the piers, except the draw pier, is 36 ft. 8 in., they being 7 ft. wide at the top and at the bottom. The draw pier is 30 ft. wide at the top and 35 at the bottom, and rests upon 427 piles, sawed off by divers, level with the river bottom. Total cost, about $300,000. The contractors were F. C. Lowthorp, of Trenton, N. J., patentee; John Beattie, of Stony Creek, stone work; S. A. Hammond, of Bridgeport, piling and timber work, and George Everett, of Allentown, Pa., superintendent of the iron work. The frame work of cast iron came from Birmingham, Conn., and the tension rods from Trenton, N. J.

THE CHANNEL TUNNEL.—In a letter to a Glasgow contemporary on this project, Mr. John G. Winton, C. E., F. R. S. S. A., of Portobello, writes:—I have long ago pointed out that this tunnel cannot be cut without providing exhausting machinery for promoting ventilation. Messrs. Hawkshaw and Co. do not consider this neccessary.

Now, I say it is imperative, both as regards driving the tunnel and effecting a thorough ventilation when in working order. Thus, these four engineers have failed in the preliminary steps. Their study of the scheme is marked at the very outset with a want of forethought. Their driftways are to be about 9 ft. square—this is simply the precautionary subways, and which are to be enlarged into one tunnel; but mark, not until the preliminary driftways are cut from shore to shore. My study of the matter points out a very different mode of action. The "twin tunnels" will be about 16 ft. in diameter, and about 25 ft. from centre to centre; thus the mid-wall between the tunnels will be 9 ft. in thickness. I take no preliminary steps after once knowing the character of the material, and which knowledge can only be acquired by piercing the strata for a considerable distance at each shore. No one would ever think of commencing such a work of vast magnitude without taking precautionary steps. Once decided on, I propose to cut and line up, as the work proceeds. My "long wall" method of working, with tunnels 16 ft. in diameter, is the only way of securing a good and lasting structure, taking into consideration that a single tunnel for double rail will be at least 24 ft. wide; this does not include the breadth of excavation necessary for the lining material. If in my "twins" cast iron must be adopted for lining up, each excavation will only be 16 ft. or so in diameter; thus a great deal of unnecessary excavation and material for lining up is saved with the twin system. And with the method I adopt for ventilation, locomotion can at all times run up to the headings, and by the system of cross shunting subways the spoil can be rapidly taken away, and the building material brought in.

THE SUEZ CANAL—A correspondent writing from Paris says: It is well known that since the opening of the Suez Canal to heavy navigation, the tolls have been levied from the tonnage officially registered on each ship's papers. Now, it has been recognized since the canal was first worked, that the majority of vessels traversing the canal carried an amount of freight largely in excess of what is stated in the papers. The interests of the shareholders suffer from this, and the administration of the Company has just appointed a commission to decide whether it will not be expedient to change the mode of operation. The commission had to ascertain what should be included according to the statutes in the tonnage capacity, and the best means of estimating the screw for each vessel. After a preliminary private discussion, these questions were submitted to a sub-commission, whose report was delivered on the 8th of November last. We believe that the conclusions of this report are as follows: The tonnage capacity is indicated by the act of concession at the volume of 1.44 cube metres applied to that portion of the ship that can be utilized of the cargo. We must remember that the modifications made in the old rules of gauge have for their object to determine the maximum tonnage without attempting to express truly the capacity, and the sub-commission think that the Company ought to establish its taxes without being guided by the official statement, arriving at the useful capacity estimated from the total capacity of the ship, and determined as equitably as possible, according to the actual condition of the load. The total capacity in tons of 1.44 cube metres being approximately double the gross tonnage calculated according to the English gauge, the amount to tax for steam vessels will be half the total capacity, and will be established on the same amount of gross tonnage. For sailing vessels it will be 0.65 of the total capacity, and will be established on the amount of tonnage 1 plus 30 per cent. The effect of these new regulations, combined with the tariff of 10 francs per ton which bear on the receipts of the Company, will be duly appreciated. Not to speak of sailing ships, steam vessels pay to-day according to their net tonnage. Considering especially English ships, which form the large majority of vessels passing through the canal, the proportion of net tonnage to gross tonnage is as 70 to 100. The receipts would thus increase this proportion—that is to say, the augmentation would be 47 per cent.

THE ST. LOUIS BRIDGE.—The progress of work on the superstructure is described as most gratifying. The masonry, which has been delayed by the unusuallysevere winter, is now, the "Republican" states being pushed with t e utmost vigor. All the granite is on hand, and the Company expect to have the masonary all completed within 4 months.

Capt. Eads is at the East attending personally to the rapid prosecution of the steel-work, and the results of operations at Pittsburgh and Philadelphia are very encouraging. The Butcher works turn out 40 steel staves a day, with the complement of steel pins, nuts, tension rods, etc. The average weight of the staves is about 600 lbs. each; they are about 12 ft. in length, 2 in. thick, and 6,000 will be required. One thousand are now finished. Each tube consists of 6 staves, and they will be put into the tubes like the staves of a barrel, with sheets of steel around them. There have been 20 tubes put together in the yards of the Keystone Bridge Co. In addition to the steelwork, the wrought iron beams, brace bars, etc., are being turned out in large quantities, and iron bridges over Main and Second streets will soon be completed.

THE torpedo boat to be built at Boston promises to be a very formidable engine of war. It will be about 170 ft. long, 35 ft. wide, and 15 ft. deep, and draw about 12 ft. of water. It will be of 350 tons burden, with two powerful propelling engines and two propeller screws. The prow of the boat is to be made sharp, and will carry a steel ram 6 ft. under water. Above the ram there will be an aperture through which will pass a long composition spar, on the end of which will be placed a torpedo of the most approved pattern. The boat will be heavily plated on the sides with iron 6 in. in thickness, while the decks are to be protected by steel plating, one inch in thickness. The estimated cost of the vessel is about $300,000, to which may be added about 50 per cent. for extras and items not counted in the estimates. Such a vessel might, perhaps, be useful in the event of war, but even then its utility would be very doubtful. It is designed to operate against blockading fleets, and, as blockades are obsolete, we doubt very much if it will ever prove more than a costly and interesting ornament to our now very harmless and inoffensive naval armament.

BOOK NOTICES.

TREATISE ON TERRESTRIAL MAGNETISM. (Blackwood and Sons.) For sale by Van Nostrand. The first half of this book contains a good deal of information, and some inquiries connected with the question of the secular variations in the magnetic elements. The author, on the supposition that the secular changes in the declination are caused by the action of a single, slowly-rotating pole on a needle which at each place is locally influenced in a definite and determinable manner, computes the declination at several places, and shows that it agrees tolerably well with actual observation. The rotating pole he places at a constant distance of 23 deg. 30 min. from the pole of the earth's axis, and gives to its rotation a period of 640 years. The latter part of the book, however, is taken up with "an hypothesis." The writer of this book, and many other such writers, would do well to remember the words of Newton, "*Hypotheses non fingo.*" The hypothesis referred to is simply this:—that the sun attracts the electric matter in the earth and carries it round in a sort of tidal wave; this causes an electric current from east to west, which causes the magnet to point to the north, and from which the writer also attempts to deduce some of the other phenomena of magnetism. There seems to us to be some ambiguity in the writer's method of expression, so that we do not clearly gather whether he intends this current to account for the whole magnetic action of the world, or only for the variations of it. A consideration of the character of the variations of the needle is sufficient to overthrow the hypothesis announced by our author. The solar diurnal variation is thus explained by him: The pole of the ecliptic revolves once a day round the pole of the earth's axis, the needle tends to follow this, and hence the solar diurnal variation. Now, we may point out a circumstance which, apparently, entirely overthrows, not only this hypothesis, but any which attempts to account for that variation by anything of the nature of the movement of a magnetic pole. At Point Barrow the needle points N.E., at Port Kennedy it points S.W., yet at each place the solar diurnal variation follows local time and exhibits precisely the same features. Standing, then, at the centre of the needle, and looking towards its marked end, that end would at both places be observed to be moving towards the left hand of the observer between the hours of 8 A.M and 1 P.M. But since the needles are pointing in opposite directions, this constitutes a movement of the marked end of the one towards the geographical west, and of the marked end of the other towards the geographical east, and this at times when the needles are under precisely the same circumstances with respect to the sun's influence. Now, no movement of the magnetic pole can account for this; it would necessarily entail a movement of the marked end of both these needles in the same geographical direction. The consideration of this phenomenon shows us that if the solar diurnal variation of the declination is to be attributed to a current, it must be one not round the magnetic pole or the geographical pole, but along the magnetic meridian. But this is not the place for us to discuss this question further at present. It would seem to be, however, rather from the consideration of such phenomena as this in a careful and accurate way, and the attempt therefrom, by induction, to arrive at laws, that we may hope to form a theory of terrestrial magnetism, than from "making an hypothesis," and then attempting to apply it to facts.—*Nature.*

QUEEN CHARLOTTE ISLANDS: A Narrative of Discovery and Adventure in the North Pacific. By FRANCIS POOLE, C.E. Edited by John W. Lyndon. (London: Hurst and Blackett, 1872.) For sale by Van Nostrand.

Mr. Poole enjoys the distinction of being the only educated Englishman who has ever lived on Queen Charlotte Islands, where he spent two years in an endeavor to develop the mineral resources of the country. The volume therefore necessarily possesses the interest attaching to a narrative of a residence in an almost unknown country. We miss, however, those touches which add so much to the charm of books of travel, which indicate that the writer has visited many men and many cities, and is capable of contrasting the natural products or the habits of the people of one part of the world with those of another. The attraction for the author to these islands was the presence of copper, to work which a company was formed in 1862. There can be little doubt that copper-veins, and probably other minerals, do exist in the islands in quantities that would amply repay the investment of labor and capital in their working. The climate appears to be equable and agreeable, the harbors are magnificent, and the soil is rich and productive, so that we may hope that at some future time Queen Charlotte Islands will become a valuable dependency of the British Crown. If Mr. Poole's volume succeeds in drawing to their capabilities the attention of those who are competent to develop their resources, it will have performed good service.—*Nature.*

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.—London: W. Mitchell & Co. For sale by Van Nostrand.

The present number (65) of this journal presents among other articles relating to army or navy affairs, an illustrated article "On the Turbine Propeller"—On Ocean Currents—On Defensive Submarine Warfare, and a Description of a Chinese Torpedo.

THE MANUFACTURE OF STEEL. By M. L. GRUNER; translated by LENOX SMITH, A. M. New York: D. Van Nostrand.

The well-known ability of the author in the line of metallurgical research will insure for this new translation an eager reception from American readers. No metallurgical industry interests the world so largely as that which has for its object the production of iron and steel, and there is no branch of manufacture which involves so many perplexing problems.

The table of contents herewith presented will afford our readers the best possible means of judging of the value of the work.

CONTENTS.—Translator's Preface; Nature of Steel; Hardness and Tenacity of Steel dependent on Carbon; Various methods for the manufacture of Steel; I. Fining Pig Iron not melted, producing malleable Cast Iron of a steely nature; II. Fining molten Pig Iron, giving solid steely products; III. Fining molten Pig Iron, giving molten steely products; Bessemer Process in France; Bessemre

Process in England; New Rolling Appliances used in England; Bessemer Steel in Sweden; Bessemer Steel in Austria; Bessemer Process in Belgium, Prussia, Russia, Italy, etc.; New Mode of assay in Bessemer fining used in Germany; Defects of the Bessemer Process—means of remedying them; Berard's Process; Fining by reaction; Experiments in manufacturing Cast Steel in the Reverberatory Furnace; The Martin Process at Sireuil; Manufacture of refined Pig Iron; IV. Manufacture of Steel by Cementation; Ordinary Cementation; Theory of Cementation; Cementation and simultaneous fusion in Crucibles; Cementation and fusion in a Cupola Furnace (Parry Process); Determination of the Carbon in Steels by the Eggertz Method; Determination of Sulphur by the Eggertz Method; Additional Note; Explanation of Plates; Appendix—The Bessemer Process in the United States.

Fine folding plates illustrate the text.

By no means the least interesting or important portion of the work is the Translator's Appendix, describing the Bessemer Process of the United States.

THEORY OF HEAT. By J. CLERK-MAXWELL, M. A. Professor of Experimental Physics in the University of Cambridge. London: Longmans & Co.

Here we have another of Messrs. Longmans' useful series of Text-books of Science. The theory of heat is a subject on which a great deal of misconception prevails, and this clear and concise statement of what is accepted, and why it is so accepted, is a valuable addition to our opportunities of acquiring a knowledge of the matter. The aim of the book, according to the author, is to exhibit the scientific connection of the various steps by which our knowledge of the phenomena of heat has been extended. The first of these steps is of course the thermometer, the second the calorimeter, by which the quantities of heat are measured. These instruments give us the means of founding a science of heat, and when their records are thoroughly understood we can investigate the relations between the thermal and mechanical properties of various substances and understand the laws of thermo-dynamics. Professor Clerk-Maxwell takes the student step by step through the various branches of the theory and cognate subjects, commencing with the "meaning of the word temperature," and ending with a chapter on the molecular theory of the constitution of bodies. In a work of this kind it is of course almost absolutely necessary to employ some mathematical formulæ, but the author has apparently taken care that they are not beyond the grasp of the average student who is earnest in a desire to acquire a knowledge of his subject. The book is illustrated with wood-cuts and explanatory diagrams, and worthily fills its place in the series.

RUDIMENTARY MAGNETISM: A Concise Exposition of the General Principles of Magnetical Science and the Purposes to which it has been Applied. By Sir S. HARRIS, F. R. S. Second edition: Revised and enlarged by Dr. H. M. Noad, F.R.S. With 165 illustrations. (Lockwood and Co., 1872.)

Snow Harris was one of those heaven-born expounders of elementary science whose works will long survive themselves and excel in some new form when their experiments and theories have become obsolete. Nothing of the kind has been written which can be compared with the three little treatises in his own department of science, which Sir William contributed to "Weale's Series." We therefore applaud Dr. Noad's discretion when he tells us that "No attempt has been made to alter in any degree the general character and style of the work." Of course the progress of science has rendered some additions here and there necessary; and Dr. Noad has distinguished his new matter by the use of brackets. Such additions relate chiefly to Faraday's latest researches in magnetism, and to the more recent investigations of the Astronomer Royal and others, respecting the deviations of the compass in iron ships. The editor has also added a chapter, giving an account of the progress of investigations in terrestrial magnetism, during the last twenty years. These investigations have a singular interest attached to their cosmical relations, and the deviations of the compass on board ship have great practical value. There is a good index, and this volume of 412 pages may be considered the best possible manual on the subject of magnetism.

NOTE BOOK ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY. By J. H. EDGAR, M. A., and G. S. PRITCHARD. (London and New York: Macmillan & Co., 1871.)

The editors—practical teachers—tell us that they hope this will prove useful as a class-book, and as a means of self-instruction to the various and constantly increasing classes of students for whom it is designed. It was originally intended as an aid in teaching the mechanical drawing class at the Royal School of Mines, from Professor Bradley's "Elements of Practical Geometry." Having been associated with him in his duties at King's College, London, and the Royal Military Academy learning the value of his treatise, the authors have produced this book for those to whom the cost of his work rendered it inaccessible. There is a large number of problems, with help for solutions.

ELEMENTARY STATICS. By J. HAMBLIN SMITH, M.A. (Cambridge: Rivingtons, 1871.)

A little work intended to explain statical principles required for the Previous Examination and the Second Examination for Ordinary Degrees, at Cambridge, is now formed also to meet the wants of pupils in schools who are preparing for the Local Examinations. It has the same merits in clear and logical statement, and numerous examples selected from papers set in University Examinations, that distinguish the rest of Rivingtons' admirable "Mathematical Series."

MISCELLANEOUS.

ICE-MAKING IN THE TROPICS.—The most marked example of the influence of radiation of heat on temperature is its influence on the production of artificial ice by the natives of India.

The fields in which the ice is made are low, flat, and open; and the ice is produced in large quantities when the temperature of the air is 16 or 20 deg. Fahr. above the freezing point. The plan followed is an interesting example of accurate observation applied

to practical purposes by a people ignorant of science. The same process has been employed from time immemorial in India with scientific accuracy; and while the theory was explained by Dr. Wells, the practical application was not so well understood; and this first led me to investigate the subject in India.

At the town of Hooghly, near Calcutta, in fields freely exposed to the sky, and formed of a black loam soil upon a substratum of sand, the natives commence their preparations by marking out a rectangular piece of ground 120 ft. long by 20 broad, in an easterly and westerly direction, from which the soil is removed to the depth of 2 ft. This excavation is smoothed, and is allowed to remain exposed to the sun to dry, when rice-straw in small sheaves is laid in an oblique direction in the hollow, with loose straw upon the top, to the depth of 1½ ft., leaving its surface ½ ft. below that of the ground. Numerous beds of this kind are formed, with narrow pathways between them, in which large earthen water-jars are sunk in the ground to fill the shallow unglazed earthen vessels in which it is to be frozen. These dishes are 9 in. in diameter at the top, diminishing to 4.3 in. at the bottom, 1.3 deep, and .3 in. in thickness; and are so porous as to become moist throughout when water is put into them.

During the day, the loose straw in the beds above the sheaves is occasionally turned up, so that the whole may be kept dry, and the water-jars are filled with soft pure water. Towards evening, the shallow earthen dishes are arranged in rows upon the straw, and by means of a small earthen pot, tied to the extremity of a long bamboo rod, each is filled about a third with water. In all cases, more water is put into the dishes nearest the western end of the beds, as the sun first falls on that part, and the ice is thus more easily removed, from its solution being quicker.

In the cold season, when the temperature of the air at the ice-fields is under 50 deg. Fahr., and there are gentle airs from the northern and western direction, ice forms in the course of the night in each of the shallow dishes. Persons are stationed to observe when a small film appears upon the water in the dishes, upon which the contents of several are mixed together, and thrown over the other dishes. This operation increases the congealing process; as a state of calmness has been discovered by the natives to diminish the quantity of ice produced. When the sky is quite clear, with gentle steady airs from the N.N.W., which proceed from the hills, of considerable elevation near Bheerboom, about 100 miles from Hooghly, the freezing commences before or about midnight, and continues to advance until morning. The thickest ice is thus formed. I have seen it $\frac{7}{10}$ in. in thickness. In a favorable night, upwards of 10 cwt. of ice is obtained from one bed.

When the wind attains a southerly or easterly direction, no ice is formed, from its not being sufficiently dry; not even though the temperature of the air be lower than when the wind is more from a northern or western point. The N.N.W. is the most favorable direction of wind for making ice, and this diminishes in power as it approaches the due north or west. In the latter case more latitude is allowed than from the N.N.W. to the north. So great is the influence of the direction of wind on the ice, that when it changes in the course of a night from the N.N.W. to a less favorable direction, the change not only prevents the formation of more ice, but dissolves what may have been formed. On such occasions a mist is seen hovering over the ice-beds, from the moisture over them, and the quantity condensed by the cold wind.

A CONTINUED range or curb of timber was discovered in pulling down a part of the keep of Tunbridge Castle, in Kent, which was built about 750 years ago. This curb had been built into the middle of the thickness of the wall, and was no doubt intended to prevent the settlements likely to happen in such heavy piles of building, and therefore is an interesting fact in the history of constructive architecture, as well as an instance of the durability of timber. In digging for the foundation of the present house at Ditton Park, near Windsor, the timbers of a drawbridge were discovered about 10 ft. below the surface of the ground; these timbers were sound, but had become black. Hakewell says that Sir John De Molines obtained liberty to fortify the Manor House at Ditton, in 1396; and it is most probable the drawbridge was erected soon after that time; and accordingly the timber had been there about 400 years.

THE question of building iron barges for canal transit is beginning to attract considerable attention at Buffalo and other cities immediately interested in canal business. The experiment of iron boats was tried many years ago, and only failed because of the then greater cost of iron over wood, and the want of facilities which now exist for repairing the iron hulls. These objections no longer exist, and we understand the relative advantages of wood and iron are to be again tested by the construction of iron barges to run in competition with boats already engaged in the canal service. The advantages claimed for iron boats are that they are lighter, and, owing to the thinness of their sides, have a greater stowage capacity for freights than the most capacious wooden boats that can pass the locks. Should these claims be substantiated by actual trial, and we have no doubt they will, it is not improbable that iron will supersede wood upon canals, as it is now doing in river, coastwise, and ocean navigation.

THE EAST RIVER BRIDGE.—The excavation under the caisson on the New York side of the river has progressed of late with much greater rapidity than was promised at the beginning of the work. The excavation of sand is nearly completed, and the operations upon the rock foundation about to commence. The uneven surface presented by the gneiss formation upon which the caisson is to rest requires yet some difficult engineering labor, but which the skill of the engineers is, doubtless, competent to overcome.

THE largest iron casting ever attempted has been successfully achieved at the Elswick Ordnance Works, Newcastle-on-Tyne, under the direction of Sir William Armstrong and Capt. Noble. It was a huge anvil block, weighing 125 tons, to be used with a 20-ton double action forge hammer, for performing the necessary forging for the 35-ton Armstrong gun.